

Guide to the Geology of the Sparta Area

Randolph and Western Perry Counties, Illinois

David L. Reinertsen
Wayne T. Frankie
Joan E. Crockett
Jonathan H. Goodwin
Philip C. Reed
Irma E. Samson



Field Trip Guidebook 1992D October 31, 1992

Department of Energy and Natural Resources
ILLINOIS STATE GEOLOGICAL SURVEY

Cover photo by D. L. Reinertsen

Barge traffic on the Mississippi River as seen from the Fort Kaskaskia Historic Site shelter. Kaskaskia Island is in the upper left of the photo.

Geological Science Field Trips The Educational Extension Unit of the Illinois State Geological Survey conducts four free tours each year to acquaint the public with the rocks, mineral resources, and landscapes of various regions of the state and the geological processes that have led to their origin. Each field trip is an all-day excursion through one or more Illinois counties. Frequent stops are made to explore interesting phenomena, explain processes that shape our environment, discuss principles of earth science, and collect rocks and fossils. People of all ages and interests are welcome. The trips are especially helpful to teachers preparing earth science units. Grade school students are welcome, but each must be accompanied by a parent or guardian. High school science classes should be supervised by at least one adult for each ten students.

Field trip guide booklets are available for planning class tours and private outings. For a list, contact the Educational Extension Unit, Illinois State Geological Survey, Natural Resources Building, 615 East Peabody Drive, Champaign, IL 61820. Call (217) 333-4747 or 333-7372.

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ILLINOIS STATE GEOLOGICAL SURVEY
Morris W. Leighton, Chief
Natural Resources Building
615 East Peabody Drive
Champaign, IL 61820



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Era	Period or System and Thickness	Epoch	Age (years ago)	General Types of Rocks
CENOZOIC "Recent Life"	Quaternary 0-500'	Holocene	10,000	Recent—olluvium in river valleys
		Pleistocene Glacial Age		Glacial till, glacial outwash, gravel, sand, silt, lake deposits of clay and silt, loess and sand dunes; covers nearly all of state except northwest corner and southern tip
	Tertiary 0-500'	Pliocene	1.6 m. 5.3 m. 36.6 m.	Chert gravel; present in northern, southern, and western Illinois
		Eocene		mostly micaceous sand with some silt and clay; present only in southern Illinois
		Paleocene	57.8 m. 66.4 m.	Mostly clay, little sand; present only in southern Illinois
MESOZOIC "Middle Life"	Cretaceous 0-300'		144 m. 286 m.	Mostly sand, some thin beds of clay and, locally, gravel; present only in southern Illinois
PALEOZOIC "Ancient Life"	Pennsylvanian 0-3,000' ("Coal Measures")			Largely shale and sandstone with beds of coal, limestone, and clay
	Mississippian 0-3,500'		320 m.	Black and gray shale at base; middle zone of thick limestone that grades to siltstone, chert, and shale; upper zone of interbedded sandstone, shale, and limestone
	Devonian 0-1,500'		360 m.	Thick limestone, minor sandstones and shales; largely chert and cherty limestone in southern Illinois; block shale at top
	Silurian 0-1,000'		408 m.	Principally dolomite and limestone
	Ordovician 500-2,000'		438 m.	Largely dolomite and limestone but contains sandstone, shale, and siltstone formations
	Cambrian 1,500-3,000'		505 m.	Chiefly sandstones with some dolomite and shale; exposed only in small areas in north-central Illinois
	ARCHEOZOIC and PROTEROZOIC		570 m.	Igneous and metamorphic rocks, known in Illinois only from deep wells

~~~~~ major unconformity

Generalized geologic column showing succession of rocks in Illinois.



## SPARTA AREA

The western part of the Mount Vernon Hill Country, a relatively level to slightly rolling surface developed by Illinoian *glaciers*\* perhaps 250,000 years ago, is the geologic setting for the eastern part of the Sparta field trip. The western part of the trip is across the more scenic, gently inclined eastern flanks of the Missouri Ozarks, also covered by the Illinoian glacier. Since then, the entire area has been eroded and covered by windblown silt.

Fossiliferous *limestones* of Mississippian age lie beneath the relatively thin glacial deposits in the western part of the field trip area. Mining of the Pennsylvanian-age Springfield (No. 5) Coal and Herrin (No. 6) Coal Members of the Carbondale Formation has made the Sparta area an important coal producer for many years.

On the Sparta field trip, we will travel through about one-third of Randolph County and the southwestern part of Perry County. The area lies approximately 285 miles south-southwest of downtown Chicago and about 115 miles south of Springfield.

## GEOLOGIC HISTORY

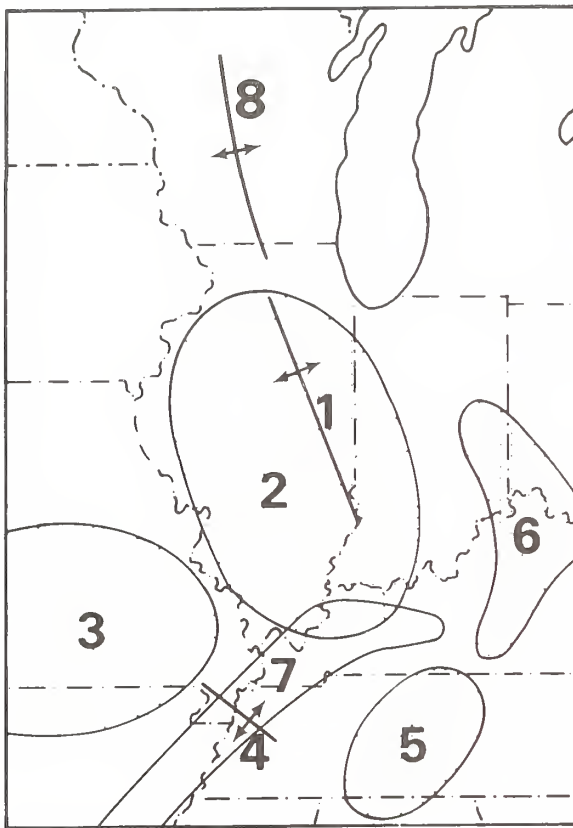
**Precambrian Era** The Sparta area, like most of the midcontinent, has undergone many changes throughout the thousands of millions of years of geologic time. The oldest rocks beneath us on the field trip belong to the ancient Precambrian (Archeozoic and Proterozoic) basement complex (see generalized geologic column on facing page). We know relatively little about these rocks from direct observation because they are not exposed at Earth's surface anywhere in Illinois. Only a few drill holes have been drilled deep enough in Illinois for geologists to collect samples of Precambrian rocks; depths range from more than 4,600 feet in the western part of the Sparta area to about 13,000 to 17,000 feet some 80 miles east-southeast in southeastern Illinois. From the samples, however, we know that these ancient rocks consist mostly of *igneous* and *metamorphic, crystalline* rocks of granitic composition. The rocks formed about 1.5 to 1.0 billion years ago when molten materials slowly solidified deep within the earth. By about 0.6 billion years ago, deep weathering and erosion had exposed the ancient rocks at the surface, forming a landscape probably similar to part of the present Missouri Ozarks. We have no rock record in Illinois for the long interval of weathering and erosion that lasted from the time Precambrian rocks were formed until Cambrian sediments were deposited across the older land surface. The interval was longer, however, than the span of geologic time from the Cambrian to the present.

Because geologists seldom see Precambrian rocks except as cuttings from drill cores, they have determined some characteristics of the basement complex by using various indirect techniques. Measurements of the earth's gravitational and magnetic fields, and seismic tests. The evidence indicates that rift valleys similar to those in east Africa began to form in what is now southernmost Illinois during the late Precambrian *Era*. These midcontinent rift structures, known as the Rough Creek *Graben* and the Reelfoot Rift (fig. 1), formed when plate tectonic movements (slow global-scale deformation) began to rip apart an ancient Precambrian supercontinent. (Continental collision is going on today as the Indian subcontinent moves northward against Asia, folding and lifting the Himalayas.) The slow fragmentation of this Precambrian supercontinent eventually isolated a new landmass called Laurasia, which included much of what is now the North American continent.

Near the end of the Precambrian Era and continuing until late Cambrian time, from about 570 million to 505 million years ago, tensional forces within the planet apparently caused block faulting (see *fault*) and relatively rapid subsidence of the hilly landscape on a regional scale. A broad trough formed extending northward from the continental margin in central Arkansas across Illinois, Indiana, and Kentucky into which a shallow sea encroached from the south and southwest.

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\* Words in italics are defined in the glossary in the back of the guidebook



**Figure 1** Location of some of the major structures in the Illinois region. (1) La Salle Anticinal Belt, (2) Illinois Basin, (3) Ozark Dome, (4) Pascola Arch, (5) Nashville Dome, (6) Cincinnati Arch, (7) Rough Creek Graben-Reelfoot Rift, and (8) Wisconsin Arch.

trough formed extending northward from the continental margin in central Arkansas across Illinois, Indiana, and Kentucky into which a shallow sea encroached from the south and southwest.

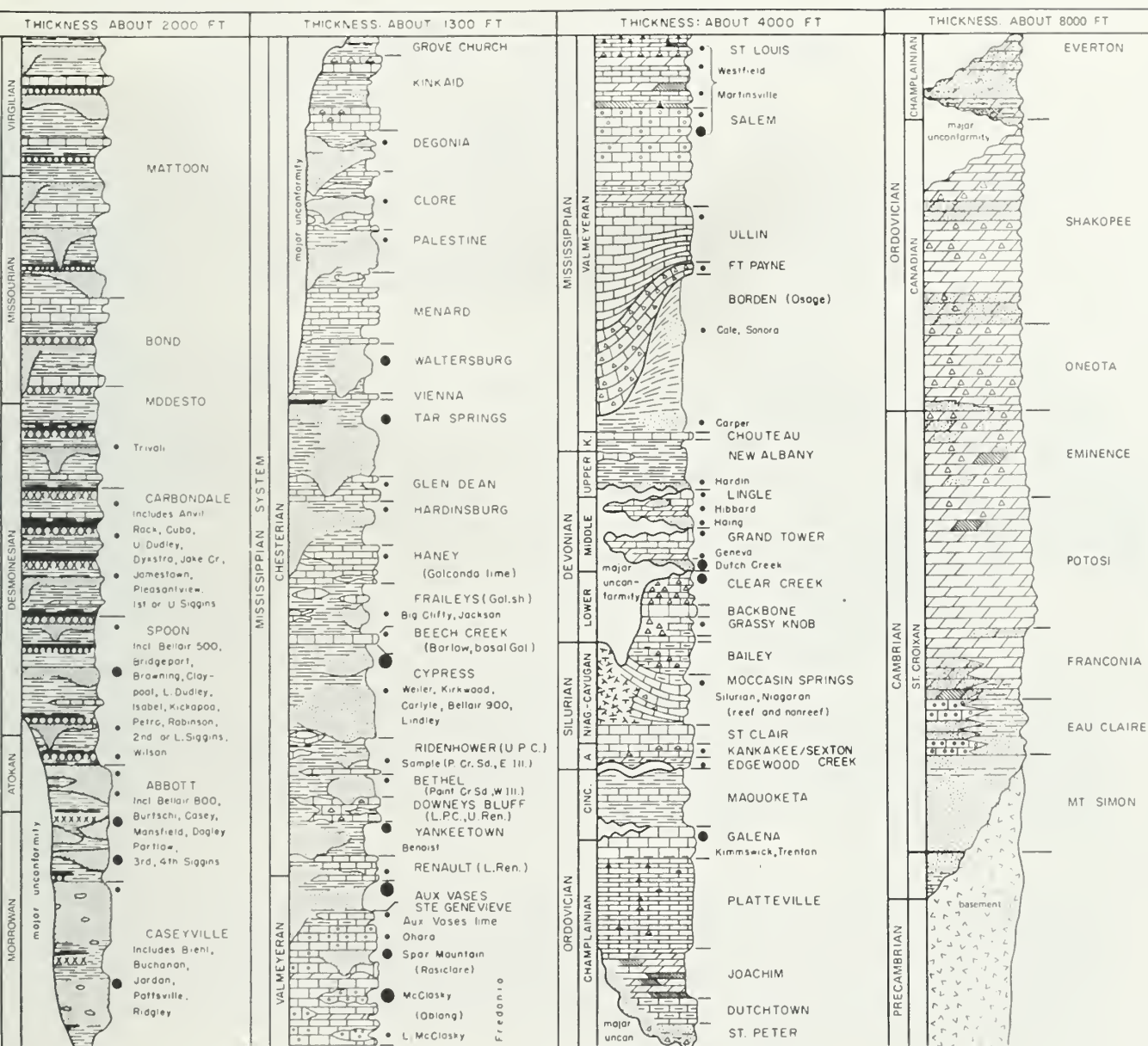
**Paleozoic Era** During the Paleozoic Era, which lasted from about 570 million years ago to about 245 million years ago, the land that now lies under southern Illinois sank slowly; layer after layer of sediment collected in the shallow seas that repeatedly covered the area. Nearly 17,000 feet of sedimentary *strata* accumulated during the 325 million years of the Paleozoic Era. These sediments, when compacted and hardened (*lithified*), and the underlying Precambrian rocks became the *bed-rock* succession.

From middle Ordovician time about 460 million years ago, until the end of the Permian Period (and the Paleozoic Era) about 245 million years ago, the midcontinent (now Illinois, Indiana, and western Kentucky), sank more slowly than it did earlier. Repeatedly, sediments poured into a broad trough or embayment covering the area and overflowed into surrounding areas as well. Shells of marine animals, muds, silts, and sands deposited in those seas over millions of years were gradually buried and lithified into solid rocks of limestone, dolomite, shale, siltstone, and sandstone.

Earth's thin crust frequently has been flexed and warped in various places by forces of compression and tension that developed within the earth at various times. Movements of the land surface, flexing upward then downward, recurred over millions of years and caused the seas to periodically drain from the region, then slowly return. When the sea floors were uplifted and exposed to weathering and erosion by rain, wind, and streams, some previously deposited strata were eroded. Consequently, not all geologic intervals are represented in the rock record of Illinois (see generalized geologic column, page iv).

**The geologic column** Figure 2 shows the succession of rock strata that a drill bit would be likely to encounter in the Sparta area. (The oldest *formations* are at the bottom of the column.) Figure 3 shows an interpretation of the general configuration and structure of sedimentary rock strata in Illi-

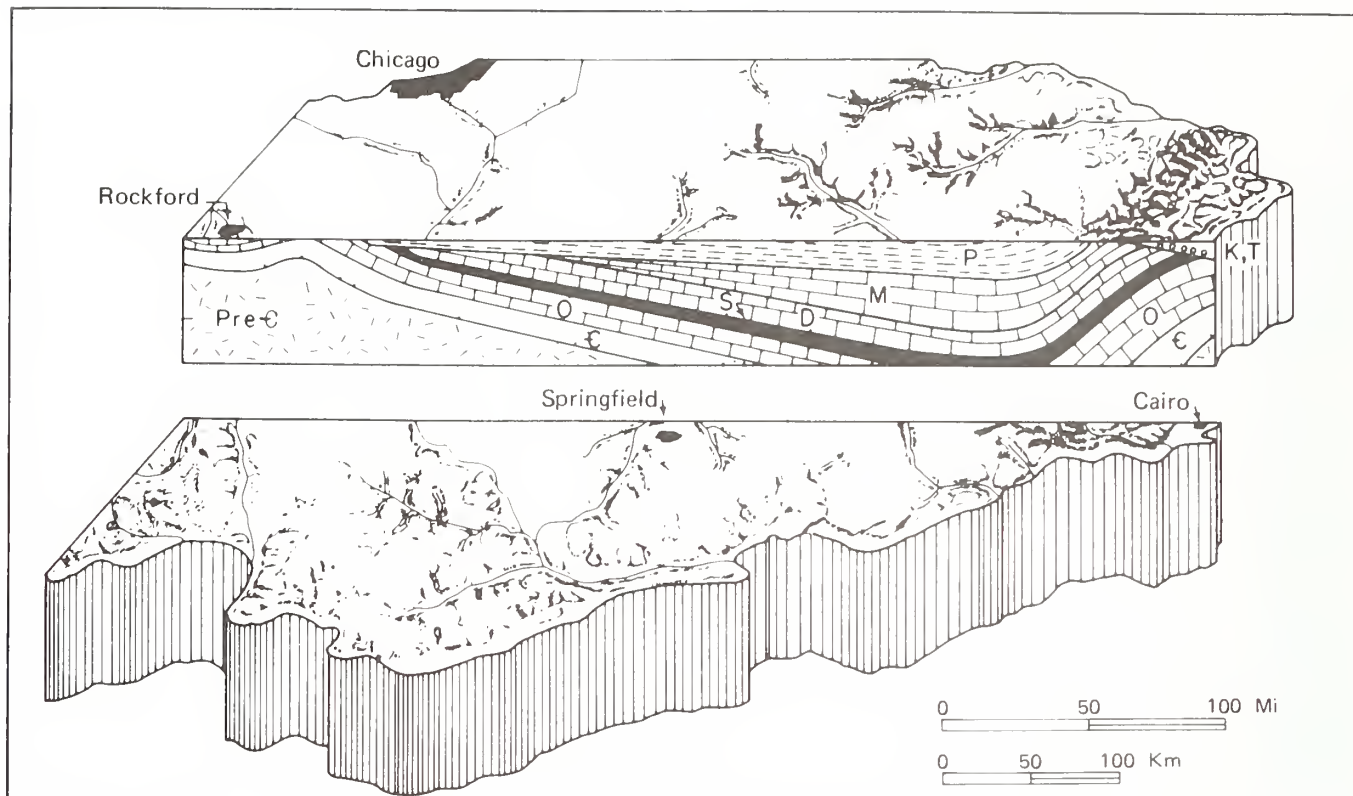




**Figure 2** Generalized geologic column of southern Illinois. Black dots indicate oil and gas pay zones. Formation names are in capitals; other pay zones are not. About 4,000 feet of lower Ordovician and upper Cambrian rocks under the St. Peter are not shown. Kinderhookian (K), Niagaran (Niag.), Alexandrian (A), and Cincinnati (Cinc.) Series are abbreviated. Variable vertical scale. Originally prepared by David H. Swann; modified from ISGS Illinois Petroleum 75.

nois. Sedimentary rocks in Illinois are classified by using formation names. Because of great similarities in appearance and composition, some formations are classified and mapped together in a unit called a *group*. Some formations contain thin, distinctive units called members.

Many of the formations in groups have conformable contacts, which means that no significant interruptions took place between deposition of the sediments of one formation and the sediments of another (fig. 2). In some cases, the composition and appearance of the rocks change significantly at the contact between two formations, even though the fossils in the rocks and the relationships between the rocks indicate that deposition was essentially continuous; this type of contact is called a *disconformity*. In other cases, the lower formation was subjected to weathering that partly eroded it



**Figure 3** Stylized north-south cross section shows the structure of the Illinois Basin. In order to show detail, the thickness of the sedimentary rocks has been greatly exaggerated and the younger, unconsolidated surface deposits have been eliminated. The oldest rocks are Precambrian (Pre-C) granites. They form a depression that is filled with layers of sedimentary rocks of various ages: Cambrian (C), Ordovician (O), Silurian (S), Devonian (D), Mississippian (M), Pennsylvanian (P), Cretaceous (K), and Tertiary (T). The scale is approximate.

before sediments of the overlying formation were deposited. When this happens, fossils and other evidence in the formations indicate a significant gap between the time when the lower unit was deposited and the time when the overlying unit was laid down. This type of contact is called an *unconformity*. If the lower strata were tilted and eroded before the overlying strata were deposited, the contact is called an angular unconformity. (Unconformities are shown as undulating lines across the rock unit column in many geologic columns.)

**Geologic framework of the field trip area** In Randolph County, the field trip area is underlain by some 4,200 feet of Paleozoic *sedimentary* rocks in the west to 7,500 feet in the east. These strata range in age from deeply buried rocks of the late Cambrian (about 523 million years old) to surface exposures of middle Pennsylvanian age (about 312 million years old). The oldest Paleozoic rocks exposed in the area are Mississippian in age; they formed from sediments that accumulated up to perhaps 336 million years ago.

This part of southwestern Illinois is called the Sparta Shelf (Meents and Swann 1965), an area that lies between the main body of the Ozarks to the west, and the Fairfield Basin, the northernmost of the deep depressions that are part of the Illinois Basin (fig. 4). From the western part of the field trip area, the Precambrian surface slopes gently eastward from -4,000 feet mean sea level (msl) elevation at slightly more than 1° for nearly 50 miles to the DuQuoin Monocline in eastern Perry County where the crystalline rock surface is at about -9,000 feet msl.

Figure 5 shows where the major bedrock units in Illinois would be located if all glacial deposits were scraped off. Bedrock exposures in the field trip area are limited essentially to outcrops along

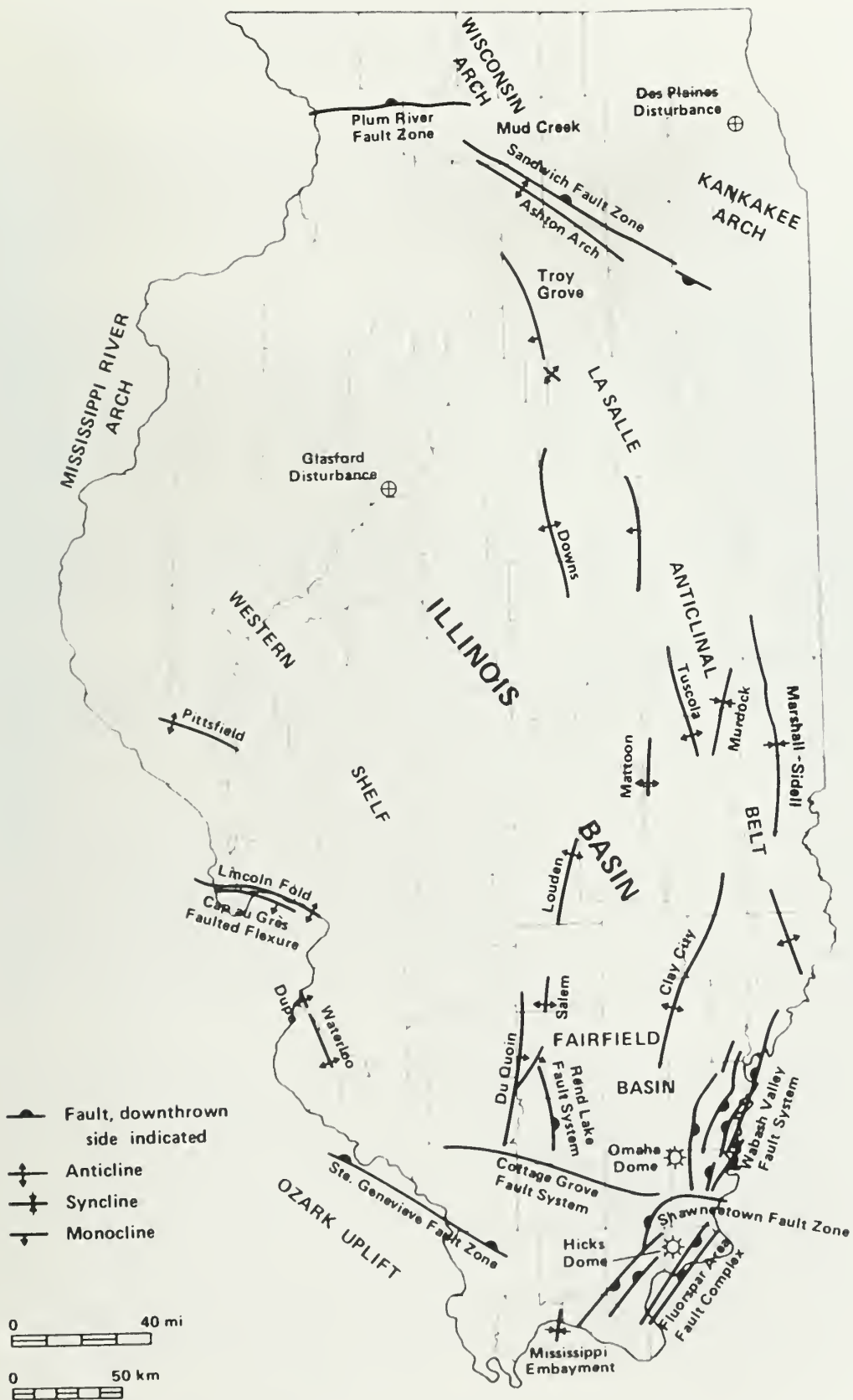


Figure 4 Structural features of Illinois.



the Mississippi River, some of its tributary streams, highway and railroad cuts, and quarries. Generally, rocks of the Mississippian System (figs. 2 and 5) occur at or just below the surface over the western part of the trip area, whereas strata of the Pennsylvanian System occur at or just below the surface in the eastern and northern parts of the area.

The depositional history of the region is linked with tectonic events. During Late Mississippian and Early Pennsylvanian time, the east coast of the present North American continent was colliding with another continent, creating the Appalachian Mountains. Several major structural features formed in the midcontinent region, including the La Salle *Anticlinal* Belt (extending from La Salle County to around Lawrence County).

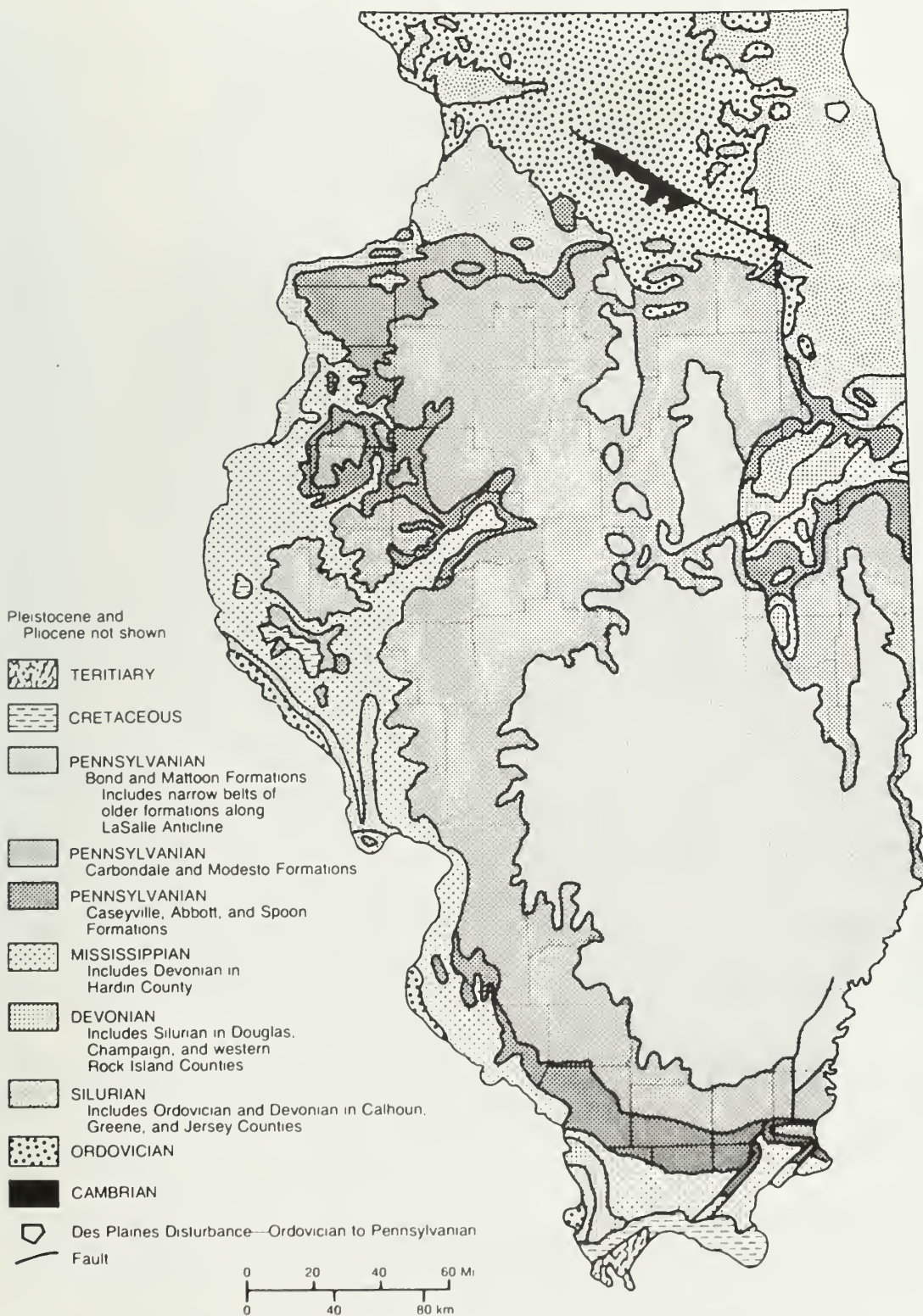
**Mesozoic and Cenozoic Eras** Although Paleozoic rocks are present everywhere in Illinois, there is no evidence to indicate that younger sediments of the Mesozoic or Cenozoic Eras accumulated during the long interval between deposition of the latest Pennsylvanian rocks and deposition of the Pleistocene glacial *drift*. This "sub-Pleistocene unconformity," the bedrock surface in Illinois, truncates all Tertiary, Cretaceous, and Paleozoic rocks down to the Upper Cambrian rocks exposed at the bedrock surface in the Sandwich Fault Zone of northern Illinois. Mesozoic rocks are absent from the stratigraphic record in almost all parts of the state, whereas late Cenozoic materials cover most of the state.

In the field trip area, except for the glacial deposits, no rocks younger than those of the Pennsylvanian Period are present. The tectonic history (the history of the earth's crustal movements) of the region during the past 570 million years is only partly known and the rest must be inferred from evidence present in other places.

During the Mesozoic and Cenozoic Eras, but before the onslaught of glaciation 1 to 2 million years ago, the land surface of Illinois was exposed to weathering and erosion. Deep valley systems were carved into the gently tilted bedrock formations. The rugged *topography* was then considerably subdued by the repeated advance and retreat of glaciers, which scoured and scraped the old erosion surface. All except the Precambrian rocks were exposed to erosion.

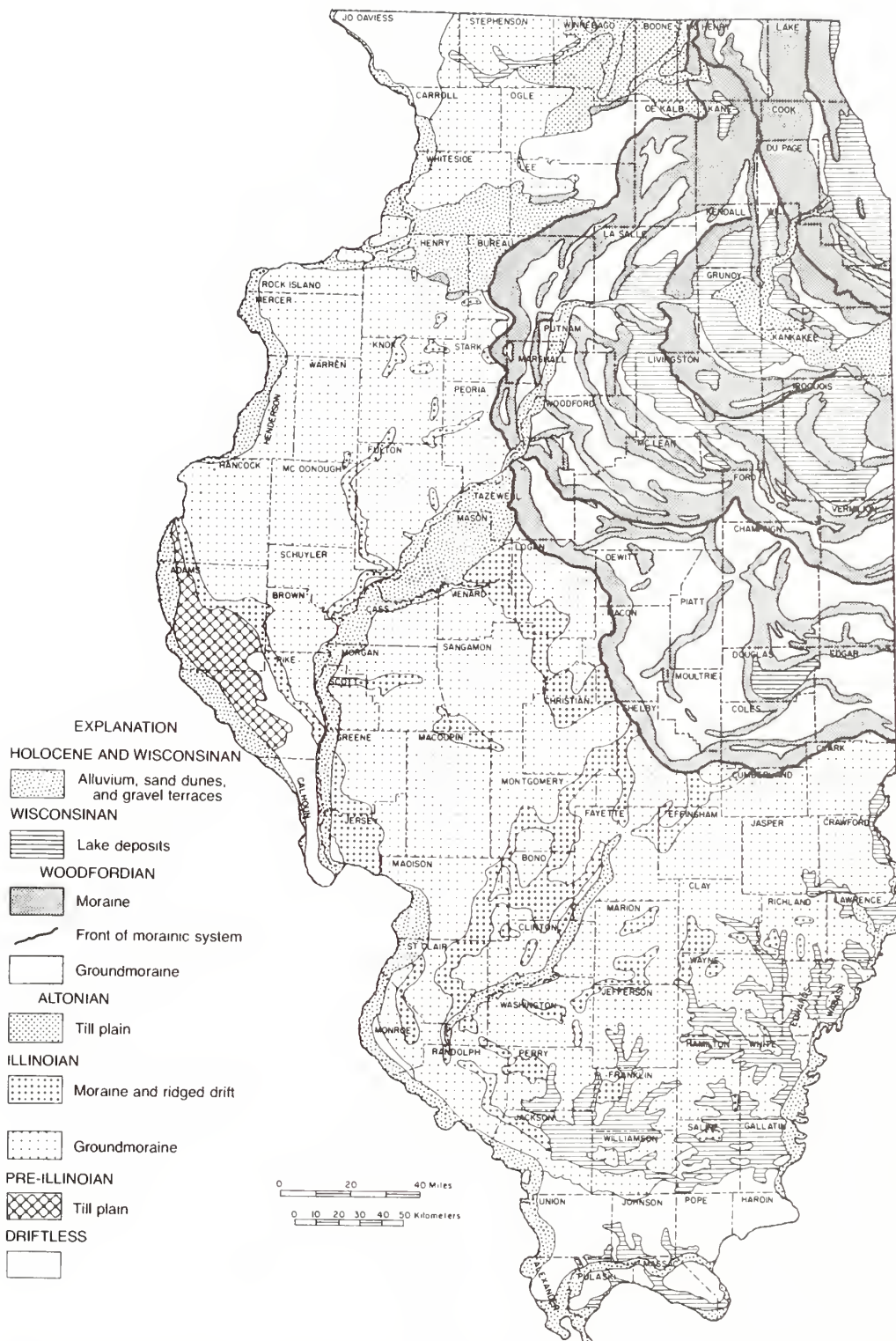
**Quaternary geology** About 1.6 million years ago, during the Pleistocene *Epoch* (commonly called the Ice Age), continental glaciers flowed slowly southward from the northern into to the midlatitudes (see appendix, *Pleistocene Glaciations in Illinois*). Several times, ice sheets covered parts of the region we know as Illinois. The last of these glaciers melted from the northeastern area of the state about 13,500 years before the present (B.P.), near the close of Wisconsinan time. Continental glaciers reached their southernmost extent in North America during the Illinoian glaciation about 270,000 years B.P. Evidence of the southern limit of glaciation can be observed in northern Johnson County, about 60 miles southeast of Sparta (fig. 6).

Until recently, glaciologists assumed that ice thicknesses of 1 mile or more were likely for these glaciers; however, the ice may have been, at most, about 2,000 feet thick in the Lake Michigan Basin and on the order of 700 feet thick across most of the land surface. That conclusion is based on the following lines of evidence: (1) inferences about the geometry, configuration and rates of flow of the ancient ice masses developed from data on the strength and other characteristics of present-day ice sheets and ice caps, such as those in Greenland and Antarctica; (2) estimates of the thickness of ice masses based on the heights of moraines and the flow directions of the ice; and (3) observations about the degree of compaction and consolidation of the drift materials that must have been under the continental glaciers that give indications about the mass/thickness of ice necessary to cause the compaction. Finally, some workers have suggested that the small amount of rebound that apparently has occurred in the Lake Michigan basin area can only be explained if the ice mass did not exceed about 2,000 feet in thickness. However, the exact amount of rebound of the region remains controversial.



**Figure 5** Bedrock geology beneath surficial deposits in Illinois.





**Figure 6** Generalized map of glacial deposits in Illinois (modified from Willman and Frye 1970).

The ice of various glaciations was active and thick enough to scour and remove part of the bedrock surface. Much of the evidence for pre-Illinoian and early Illinoian glaciations is missing from the northern part of our state; it was removed by the effects of the subsequent Wisconsinan glaciation. The last major glacial advance, the Wisconsinan Woodfordian, began about 25,000 to 22,000 years B.P. Ice from an accumulation center where Labrador now lies slowly flowed southward through the Lake Michigan Basin to form the Lake Michigan Glacial Lobe that spread out across the region that became northern Illinois.

The thickness of sediments deposited by the glaciers (glacial drift) ranges from a few feet to somewhat more than 50 feet over much of the field trip area. Thicknesses of about 100 feet occur in the preglacial drainage locations of Mary's and Kaskaskia Rivers and along the Mississippi River.

The landscape in the Sparta area developed on bedrock that is covered by relatively thin Illinoian glacial deposits that were eroded during and after glaciation. Although younger Wisconsinan glaciers of the Woodfordian Substage only reached the Shelbyville area, about 100 miles northeast of Sparta, outwash materials from the waning ice front were being transported toward the sea by meltwater rivers rushing through this area. Each summer, floods of sediment-laden meltwater deposited layers of mud, silt, sand, and gravel across the floodplains of the rivers. With the coming of winter, melting decreased and floodplains that were water-covered during the summer were exposed to harsh, bitter, drying winds. The cold winds winnowed out and picked up huge clouds of dust and silt and sand from the floodplains and spread the material across the land. Windblown fine sand and some of the coarser silt were deposited along the valley walls of the outwash streams; finer materials were carried across the uplands where they were deposited as a blanket on material called *loess* (rhymes with bus) that became thinner eastward away from the streams. The Mississippi River was a major source of this loess, but other floodplains were local sources. Loess deposits are nearly 25 feet thick along the east Mississippi Valley walls, but thin to less than 4 feet about 20 miles away in northeastern Randolph County. The loess helped to subdue the surface features developed on the eroded glacial materials. Loess deposits were being eroded during and after the Woodfordian glaciation, which reached its maximum western and southern extent about 21,000 years B.P.

## GEOMORPHOLOGY

### Physiography

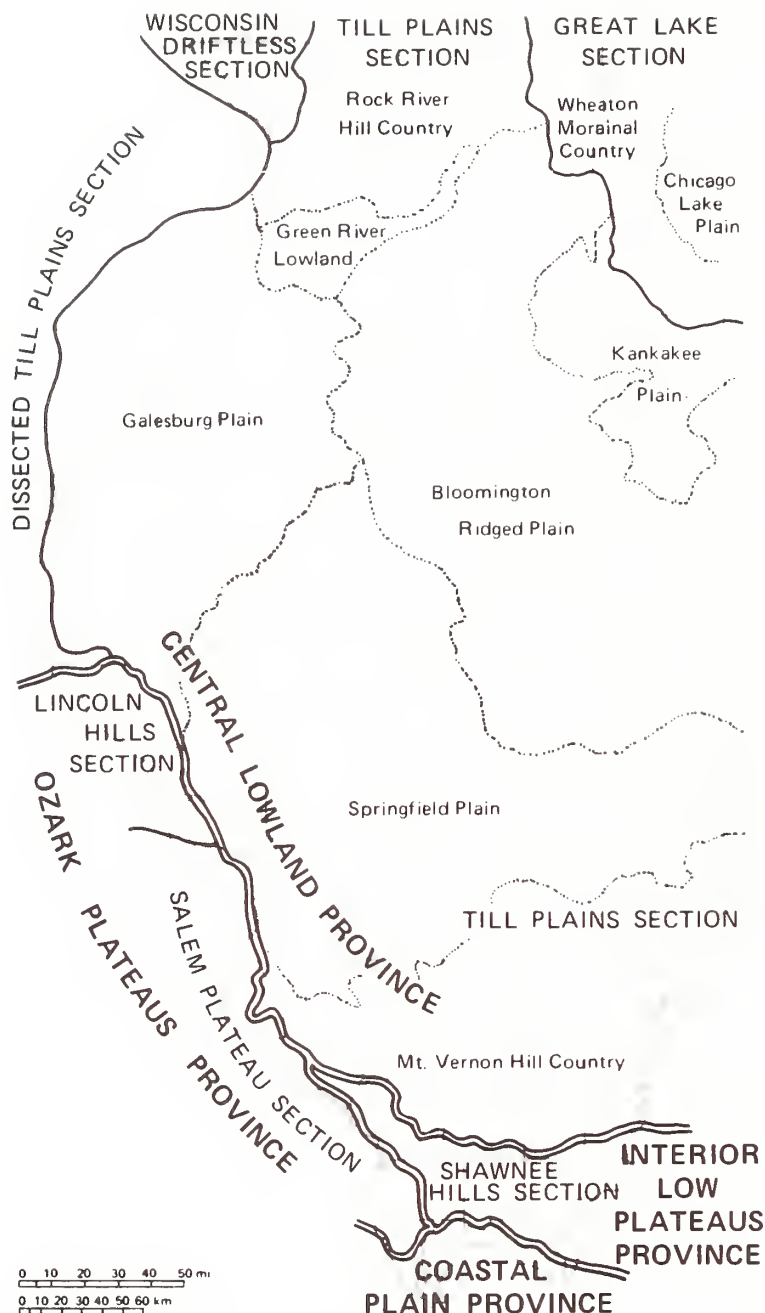
The physiographic contrasts between various parts of Illinois are due to several factors, including the topography of the bedrock surface, the extent of the various glaciations, differences in the thickness of the glacial deposits, differences in age of the uppermost glacial drift, and the effects of erosion on the land surface.

The Sparta field trip area embraces the southwestern Illinois part of the Till Plains Section, the division of the Central Lowland Physiographic Province (fig. 7) that embraces about four-fifths of Illinois, and the northern part of the Illinois portion of the Salem Plateau Section, a division of the Ozark Plateaus Province.

The Till Plains Section is characterized by broad *till* plains that are relatively uneroded (a youthful stage of erosion), in contrast to the maturely eroded Dissected Till Plains on older drift-sheets in Iowa. In Illinois, the Section has seven subdivisions: the Bloomington Ridged Plain, Galesburg Plain, Green River Lowland, Kankakee Plain, Mt. Vernon Hill Country, Rock River Hill Country, and the Springfield Plain.

The Salem Plateau Section encompasses the major part of the Ozark Dome in southern Missouri. Two small segments lie east of the Mississippi River in Illinois. The eastern margin of the northern segment, in the Sparta area, closely follows the overlapping edge of the Pennsylvanian strata.

Sparta is located in the western part of the Mt. Vernon Hill County. Leighton and others (1948) describe the Mt. Vernon Hill Country as a region of mature topography with low relief and limited up-



**Figure 7** Physiographic divisions of Illinois.

land prairies and broad alluviated valleys along the larger streams. Because of the thinness of drift in this area, glacial landforms (such as moraines or large kames) are either lacking or difficult to recognize. No Pre-Illinoian drift deposits are known in this field trip area.

According to Horberg (1946) and others (Leighton et al. 1948), prior to glaciation an extensive lowland called the "central Illinois peneplain" had been eroded into the relatively weak rocks of Pennsylvanian age east and south of the present-day Illinois River. The surface appears to have been one of low relief and sloped gently southward. Apparently, just before the advent of glaciation, an extensive system of bedrock valleys was deeply entrenched below the central lowland surface level. The gross features of the Till Plains Section as well as local features of the Mt. Vernon Hill Country are determined largely by this preglacial topography. As glaciation began, streams prob-



ably changed from erosion to aggradation, that is, the streams began to build up and fill in their channels because they did not have sufficient volumes of water to carry and move the increased quantities of sediments. There is no evidence to date to indicate that the early fills in these preglacial valleys ever were completely flushed out of their channels by succeeding meltwater torrents during deglaciation.

Leighton, Ekblaw, and Horberg (1948) note that the northern segment of the Salem Plateau Section is developed on Mississippian strata of the Chester Series that lie on the back slope of the *cuesta* that flanks the Ozark uplift on the north and east sides. The plateau is submaturely dissected; and gently rolling summit areas that are probably remnants of the Ozark *peneplain* occur along the central ridge. Because of the glacial drift mantle, the topography is not as rugged here as in other parts of the plateau. Karst features are present at many places in the area. Although the central ridge forms the watershed for tributary drainage, the Mississippi and Kaskaskia Rivers cross the ridge without regard to structure, which shows that they were preglacial streams that remained in their courses during the long, slow uplift of the Ozark peneplain. During the glacial period, the preglacial topography was modified by *alluviation* of the major valleys and by deposition of loess on the uplands. The Mississippi and Kaskaskia River valleys have broad alluvial flats and steep walls, whereas most of the tributaries are youthful in their development.

### **Drainage**

In the Sparta area, a drainage divide in the network of buried preglacial valleys extends southwestward from Nashville through Coulterville and Sparta to the Mississippi Valley on the north side of Chester. Drainage to the northwest of the divide was through the Ancient Kaskaskia River and then southwest to the Ancient Mississippi River. Most of the drainage southeast of the divide in the field trip area was through the Ancient Mary's River south-southwest to the Ancient Mississippi. A small part of the drainage, on the eastern edge of the field trip was southeastward through the Ancient Big Muddy River to the Ancient Mississippi.

Most streams in the modern drainage system of the Sparta area have low *gradients* (bottom slopes) and are actively widening their bottomlands. The uplands generally have good natural drainage, with the possible exception of small tracts in scattered upland prairies such as Flat Prairie north of Sparta. Because the Illinoian drift and Wisconsinan loess are relatively thin through much of the area, the modern courses of Kaskaskia and Mary's Rivers and their larger tributaries generally follow closely the alluviated preglacial bedrock valleys in the area.

### **Relief**

The highest land surface elevation along the Sparta field trip route is 680 feet msl just south of the Ft. Kaskaskia Road and about 0.4 mile west of SR 3. The lowest elevation is less than 360 feet msl, the water surface of the Mississippi River below Ft. Kaskaskia. Therefore, the maximum relief along the field trip route, calculated as the difference between the highest and lowest surface elevations, is about 320 feet within a horizontal distance of 1.45+ miles. The maximum local relief is slightly more than 240 feet from the ridge in Ft. Kaskaskia Historic Site to the Mississippi River 0.2+ mile away. Generally, south and west of Sparta surface reliefs of 50 to 70 feet are fairly common, with scattered locations showing 100 feet or slightly more.

## **MINERAL RESOURCES**

### **Groundwater**

A mineral resource frequently overlooked in assessing an area's natural resource potential is *groundwater*. Its availability can be essential for orderly economic and community development. Groundwater is the water supply for more than 5 million people who live in 88% of the state. The other half of the population, mainly people living in Chicago, rely on surface water supplies such as Lake Michigan. Consequently, studies of groundwater resources are an integral part of the research and service programs at the Illinois State Geological Survey (ISGS).

Groundwater resources are obtained from underground formations called aquifers. *Aquifer* materials (sand and gravel, sandstones, fractured rocks) are water-saturated and permeable enough to transmit usable quantities of water to wells or springs. The source of groundwater is precipitation—rainwater or melting snow that enters and infiltrates through the soil. Soil moisture that is not evaporated or used by plants percolates or seeps downward (because of gravity) and replenishes the groundwater supply; this is called recharge. Recharge for most shallow wells occurs within a few miles of the well.

The water-yielding capacity of an aquifer is evaluated by constructing wells into it. Test wells are pumped and water samples collected to determine the quality and quantity of the water supply.

Pryor (1956) reported that the upland in Randolph and Perry Counties contains thin glacial deposits that are generally unfavorable for developing drilled wells in sand and gravel. However, where present, the thin sands and gravels generally are suitable only for domestic water supplies. Thick *permeable* sand and gravel deposits occur in the Mississippi Valley and are favorable for locating high volume sources for industrial and municipal groundwater supplies. Some favorable deposits also may be present in the Kaskaskia Valley in northwestern Randolph County. Only scattered, thin, sand and gravel deposits are present in the valley fill of Mary's River. Because the unconsolidated materials overlying bedrock are recharged by local precipitation, they are susceptible to surface contamination.

Drilled wells in upper bedrock strata generally obtain groundwater from Lower Pennsylvanian sandstones in the northeastern half of Randolph County and western Perry County. The depth to these thick sandstones ranges from less than 100 feet along the western border of the Pennsylvanian outcrop to more than 600 feet east of Sparta and Percy. Mississippian Chesterian Series strata are water-yielding in the western part of Randolph County, with good supplies extending for a short, unknown distance eastward beneath the overlying Pennsylvanian rocks. The basal Chesterian Aux Vases sandstone is water-yielding in northwestern Randolph County where it provides modest amounts of groundwater for industrial and municipal purposes. Domestic groundwater supplies are readily obtained from the Chesterian strata where they underlie glacial deposits. These rocks are also recharged by local precipitation. The only filtering effect of recharge water is through clay present in the overlying glacial deposits. Where the glacial units are thin or absent and the bedrock is exposed at the surface, recharge enters directly into the rock units and there is little, if any, filtering of contaminants.

Water supply information for the following communities on the field trip route has been compiled from Illinois State Water Survey data:

Sparta, Randolph County—226.8 million gallons annually of surface water from 2 reservoirs and Kaskaskia River; 7,000 population.

Cutler, Perry County—16.2 million gallons annually from 2 wells between 590 and 595 feet deep into Pennsylvanian sandstone; 120-150 gpm from each well; 1,200 population.

Percy, Randolph County—27.0 million gallons annually from 2 wells between 462 and 482 feet deep into Pennsylvanian sandstone; 150-180 gallons per minute (gpm) from each well; 1,125 population.

Steeleville, Randolph County—81.1 million gallons annually from 6 wells between 285 and 335 feet deep into Pennsylvanian sandstone; 95-116 gpm from each well; 2,200 population.

### **Mineral Production**

Of the 102 counties in Illinois, 98 reported mineral production during 1990, the last year for which totals are available. The total value of all minerals extracted, processed, and manufactured in Illinois was \$2.9 billion (Samson, in preparation).



In 1990, Illinois ranked fifth in the nation in coal production; 61.7 million tons were mined valued at \$1,709.8 million. Also in 1990, the nearly 20 million barrels of crude oil produced were valued at \$406.5 million, ranking the state 13th. In 1989, total Illinois stone production was estimated at 62.7 million tons, valued at \$283.1 million; reported tonnage placed Illinois fourth among 48 states reporting production of crushed and broken stone. Also in 1989, the latest year for which data are available, 54 of Illinois' counties produced stone; 103 companies operated 178 quarries. Stone is used primarily for construction aggregate, especially as road-base stone, but it is also used in chemical and agricultural production. Illinois ranks seventh in the production of sand and gravel during 1990, with a total extraction of 32.4 million tons valued at \$104.7 million at the pit. In 1988, 107 companies operated 157 pits at 143 operations in 55 counties. Less than 0.7 million cubic feet of natural gas valued at nearly \$1.5 million were produced in the state during 1990.

Randolph County ranked fourth among Illinois counties reporting mineral production during 1990. Coal, stone, crude oil, sand and gravel, and natural gas were the primary minerals extracted. The total value of minerals produced amounted to nearly \$179.1 million.

Perry County ranked first among Illinois counties reporting mineral production during 1990. Coal and crude oil were the minerals extracted.

### GUIDE TO THE ROUTE

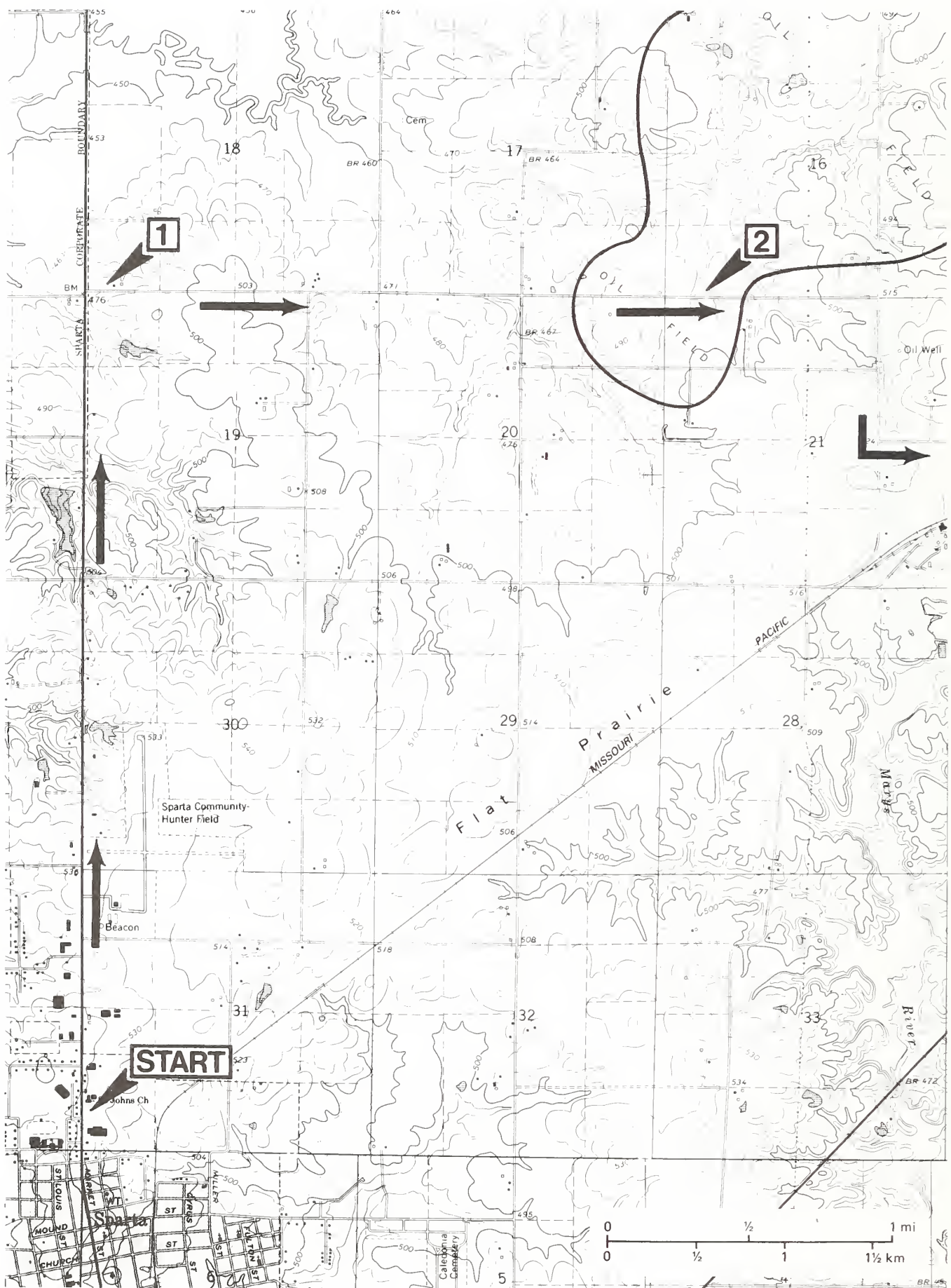
Assemble in the parking area on the northeast side of Sparta High School in the north part of Sparta (NW NE SE SE SE Sec. 36, T4S, R6W, 3rd P.M., Randolph County; Tilden 7.5-Minute Quadrangle [38089B6])\* . Mileage calculations will begin at the northeast entrance to the parking lot at the corner of North Maple Street and West Dean Ave.

**You must travel in the caravan. Do not drive ahead of the caravan!** Please keep your headlights on while in the caravan. Drive safely but stay as close as you can to the car in front of you. Please obey all traffic signs. If the road crossing is protected by an emergency vehicle with flashing lights and flags, then obey the signals of the ISGS staff directing traffic. When we stop, park as close as possible to the car in front of you and turn off your lights.

Some stops on the field trip are on private property. The owners have graciously given us permission to visit on the day of the field trip only. Please conduct yourselves as guests and obey all instructions from the trip leaders. So that we may be welcome to return on future field trips, please do not litter or climb on fences. Leave all gates as you found them. These simple rules of courtesy also apply to public property. If you use this booklet for a field trip with your students, youth group, or family, you must (because of trespass laws and liability constraints) get permission from property owners or their agents before entering private property.

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\*The number in brackets [38089B6] after the topographic map name is the code assigned to that map as part of the National Mapping Program. The state is divided into 1° blocks of latitude and longitude. The first two numbers refer to the latitude of the southeast corner of the block; the next three numbers designate the longitude. The blocks are divided into sixty-four 7.5-minute quadrangles; the letter refers to the east-west row from the bottom and the last digit refers to the north-south column from the right.



---

| Miles<br>to next<br>point | Miles<br>from<br>start |                                                                                                                                                                                                                                                 |
|---------------------------|------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0.0                       | 0.0                    | STOP: 3-way at North Maple Street and West Dean Avenue. CONTINUE AHEAD (east) on W. Dean Ave.                                                                                                                                                   |
| 0.05                      | 0.05                   | STOP: 1-way at T-intersection with N. Market St. and State Route (SR) 4. TURN LEFT (north).                                                                                                                                                     |
| 0.15                      | 0.2                    | CAUTION: commercial development on both sides of the highway.                                                                                                                                                                                   |
| 1.05                      | 1.25                   | CAUTION: highway narrows to 2 lanes.                                                                                                                                                                                                            |
| 1.25                      | 2.5                    | The area to the left has been recently surface mined and still has the large equipment used in the mining operations.                                                                                                                           |
| 0.3                       | 2.8                    | Prepare to turn right.                                                                                                                                                                                                                          |
| 0.15+                     | 2.95+                  | TURN RIGHT (east) at T-intersection on to 25.00N (Township Road 47A) and prepare to park.                                                                                                                                                       |
| 0.05-                     | 3.0                    | PARK along the right shoulder as far off the road as you can safely. BE CAREFUL of traffic on this road and in crossing SR 4. GATHER at the road intersection and follow directions for crossing SR 4. Please use EXTREME CAUTION in this area! |

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**STOP 1** At Peabody Coal Company's River King Mine No. 6 Pit we will have an opportunity to see the huge electric shovel and the drag lines that are used in uncovering the coal and handling the spoil piles for later reclamation efforts (parked: N edge near NWcor Sec. 18, T4S, R5W, 3rd P.M., Randolph County; Tilden 7.5-Minute Quadrangle [38089B6]; the stripping shovel location: S edge SE SE SE Sec. 13, T4S, R6W, Randolph County; Tilden 7.5-Minute Quadrangle [38089B6]).

Peabody Coal Company began an aggressive expansion program in 1957 with the opening of the River King Mine near Freeburg, Illinois. Over the years the company has expanded its operations through a series of six pits that extended some 20 miles south-southeast to this location on the north side of Sparta. Those mines produced about 10 million tons of coal. In addition to supplying coal to nearby electricity generating plants, Peabody also ships coal by rail, truck, and barge to other customers both in-state and out-of-state.

Prior to 1976, production tonnages from River King No. 6 were included with River King No. 3 in St. Clair County. Production from 1976 through 1991 totaled more than 26.3 million tons of Herrin (No. 6) Coal. This mine shipped 1.45 million tons of steam coal for power generation during 1991. During the late 1960s, when River King Mine was operating at peak production levels, the mine employed more than 500 people. No. 6 mine employed about 140 people in mid-1992. However, because of a lack of strippable coal reserves in this vicinity the No. 6 Mine closed its surface-mining operations in August 1992. Some coal is being produced from two drift mines operating from the east side of the box cut. About 65 people are employed in reclamation work that will continue for nearly 2 more years.

The following geologic section is a composite of two descriptions made by John Nelson and Phil DeMaris, ISGS Coal Section, in October 1991:



Surficial materials, not examined; 20 feet.

Piasa Limestone, light gray, in beds about to 1 foot thick; dolomitic; small vugs; scattered large echinoderm fragments; green claystone partings; sharp basal contact slightly undulating; 10 feet-.

Claystone, greenish gray; 0-1 foot.

Coal (?) or black, carbonaceous shale; Danville (No.7) Coal horizon; 0.1-1 foot.

Claystone, greenish gray to olive gray; sharp contact; 2-3 feet.

Sandstone, light gray; fine grained; micaceous; clayey; laminated to thickly bedded; 4-5 feet.

Claystone and siltstone, mottled and variegated greenish and olive gray, dark gray with some red and purple; strongly calcareous, at least in lower part; 8-10 feet.

Bankston Fork Limestone, light gray; lime mudstone with scattered fossil fragments and occasional whole brachiopods; very silty and argillaceous; shale partings near top, otherwise a single massive bed; sharp contact, slightly undulating; 2-3 feet.

Shale, grayish black; upper portion blocky and relatively soft, becoming harder downward; fissile; calcareous; no fossils noted; grades downward into limestone; 4-5 feet.

Conant Limestone, dark gray lime mudstone with scattered fine fossil fragments and whole brachiopods; single massive bed; 2 feet.

Shale, grayish black; hard; calcareous grading to limestone; blocky to fissile; unidentified very fine fossil fragments; gradational basal contact; 2 feet.

Brereton Limestone, dark gray lime mudstone with scattered fine fossil debris; appears massive; 4-5 feet.

Anna Shale, black; moderately fissile; 2 feet.

Herrin (No. 6) Coal, floor of pit; 5-6 feet.

Much of the coal from this mine was used for steam generation in the Illinois Power Company's Baldwin electric power plant located about 10 miles west. During the 1950s, Peabody Coal Company recognized that mining and reclamation had to work hand-in-hand in order to be a successful venture. Its Operation Green Earth program was initiated to carry out the long period of reclamation needed for returning the stripped-over lands to environmentally acceptable productive use. The company has placed as much land into this reclamation program as it mines annually (Excavating Engineer 1964). They employ foresters, biologists, and recreational specialists to carefully plan and execute the redevelopment of the land. In addition to forests, some acreage is used for pastures, lakes for fishing and water sports, and some home sites. Cover for wild game is planted, as well as forage crops for the game. Wild game is regularly released in certain designated areas.

The huge stripping shovel in the No. 6 Pit here, a Bucyrus-Erie 3850-B, was built on site in 1964 several miles west and north of here; 300 railroad flat cars transported the parts from the fabrication plant in Wisconsin to the mine. This is the largest electric shovel in the world (a somewhat larger shovel located several miles southeast of here was destroyed by fire in September 1991 and then scrapped). This shovel stands as high as a 20-story building; its operator's cab is five stories above the coal upon which the shovel stands. The dipper, or bucket, has a capacity of 140 cubic yards, which means that it can dig about 250 tons of *overburden* with each bite; eight small Fords would fit in the bucket. The boom and rotating machinery room allow the overburden to be moved more than 400 feet and stacked on a 150 foot high spoil pile. The hoist ropes (wire cables) are 3-3/8 inches in diameter. The shovel's 100 electric motors, ranging from 1/4 to 3,000 horsepower, daily use enough electricity to supply a city of 15,000 people. This huge machine is as wide as an eight-lane highway (nearly 74 feet); its dual crawlers are about 89 feet long from the front of the machine to the back. Each of the eight crawlers is 8 feet high by 8+ feet wide by 41 feet long and pow-

ered by a 250 HP electric propelling motor. These crawlers support the 10,000 ton machine and distribute its load across the coal so that its bearing weight is only 56 pounds per square inch.

Shovel operator Jim Pagliai manned this machine on its first and last "bites." There were two other operators so that the shovel could be operated on three shifts. According to Pagliai (Pulse, 1992), the shovel has dug the equivalent of two Panama Canals. The 3850 has moved in excess of 731 million tons of overburden.

Local interests around Sparta would like to see the 3850-B power shovel set aside as a tourist attraction (County Journal, 1992). Because it is the largest shovel of its kind in the world, they feel it is proper to have it on display for future generations to view. However, it is unknown where the source of funding for preparing the machine for display and its annual maintenance would come from. Furthermore, there would undoubtedly be high costs for insurance and site supervision.

---

|      |       |                                                                                                                                                                                                  |
|------|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0.0  | 3.0   | Leave stop 1 and CONTINUE AHEAD (east).                                                                                                                                                          |
| 0.45 | 3.45+ | The rise that we are crossing brings us up to the upland in this area. CONTINUE AHEAD (east) on this road for the next 2.25 miles.                                                               |
| 0.9  | 4.35  | Cross creek that drains northwest to Kaskaskia River.                                                                                                                                            |
| 0.1+ | 4.45+ | CAUTION: at crossroad (2950E) you are leaving the blacktop.                                                                                                                                      |
| 0.3+ | 4.75+ | Oil pump-jacks on both sides of the road indicate that we are in the Tilden Oil Field. Note the pump-jacks and tank batteries in this area.                                                      |
| 0.3+ | 5.1   | PARK along the right shoulder as far off the road as you can safely. Do NOT (1) enter the fields on either side of the road; (2) touch any valves on the tanks or pumps; (3) climb on any tanks. |

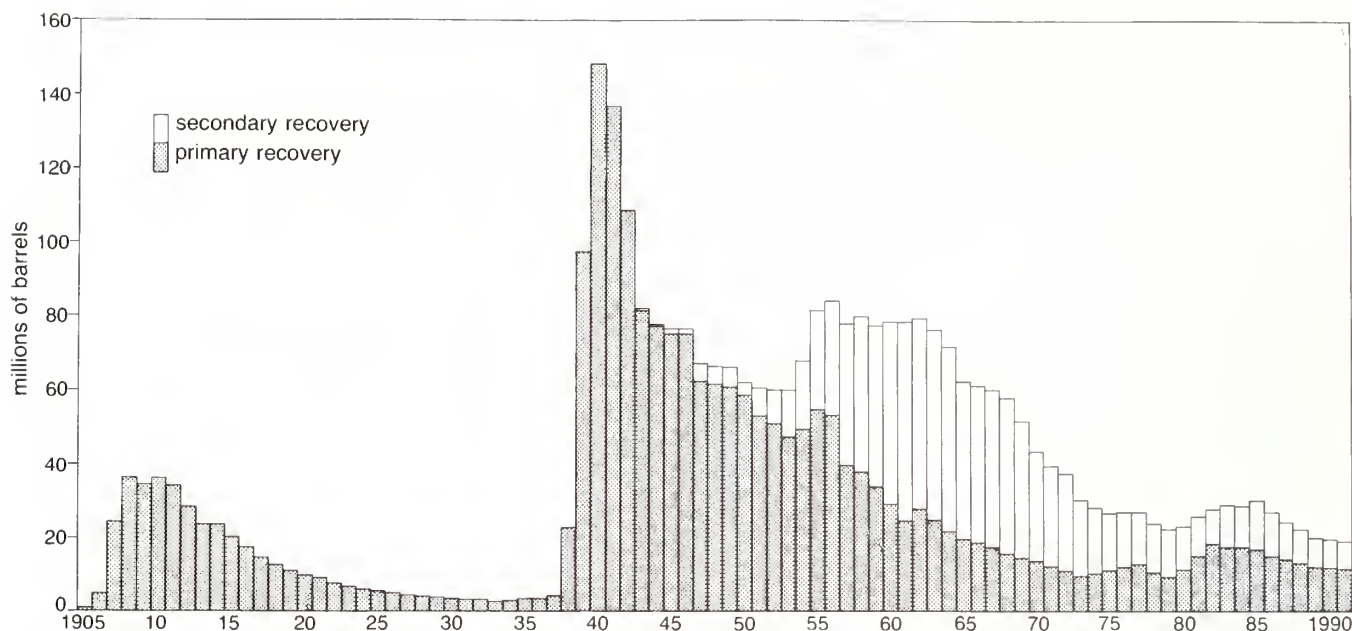
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**STOP 2** This locality will give you the opportunity to hear about the occurrence of oil in the Tilden Field and in Illinois across the road from the tank battery (N edge NE NW NW Sec. 21, T4S, R5W, 3rd P.M., Randolph County; Tilden 7.5-Minute Quadrangle [38089B6]).

Portions of the following discussion first appeared in the Mt. Vernon Area Guidebook (Reinertsen et al. 1989). Oil and gas exploration has been an important industry in Illinois since production was first established here more than 100 years ago. The success of those early explorers encouraged additional exploration throughout the state and eventually led to a peak annual production of nearly 148 million barrels in 1940—ranking Illinois as the fourth largest oil-producing area in the world. Annual production has declined since then to a total of about 20 million barrels of oil last year (fig. 8). Much of this decline is due to the difficulty in locating new oil and gas reservoirs. Nevertheless, approximately 3.3 billion barrels of oil, worth over \$15 billion, has been produced in Illinois thus far and it is hoped that ongoing projects will add to that total.

Exploration for oil and gas in Illinois is concentrated in the southern half of the state where good oil and gas reservoirs are known to exist (fig. 9). Oil and gas are thought to have originated in organic-rich shales that were buried and, over tens of millions of years, subjected to sufficient heat and pressure to generate hydrocarbons. These hydrocarbons then slowly migrated through microscopic spaces in the rocks into more porous sandstones, limestones, and dolomites from which we pump out the oil today. Since hydrocarbons float on water, and since most porous rocks contain water or saltwater, oil and gas typically "float" upward through the porous rocks until they reach a barrier to further migration. For this reason, oil and gas are commonly found at the highest position of a porous rock layer, such as at the top of an *anticline* (fig. 10).





**Figure 8** Annual crude oil production in Illinois, 1905-1988.

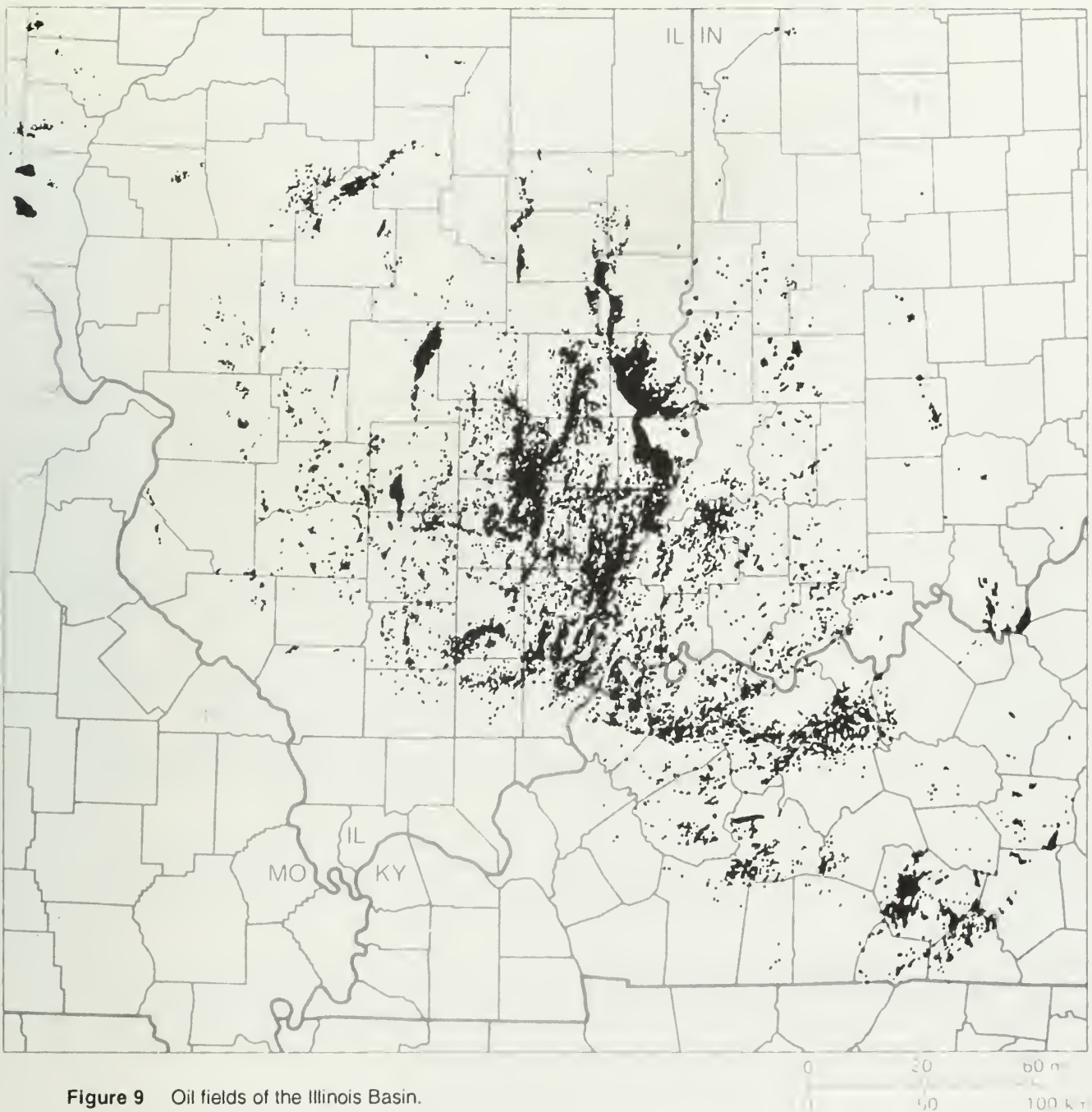
Most of the oil and gas fields in Illinois are located on anticlines at depths ranging from 400 to 5,400 feet below ground level. Geologists can locate these anticlines by studying rock layers that are exposed at the surface, by studying information from other wells nearby, and/or by utilizing geophysical tools, such as seismic data, which can detect changes in some kinds of rock layers deep underground.

Because small anticlines are hard to find, and because changes in rock characteristics are difficult to predict, most exploratory holes, or "wildcats," fail to find oil. Typically, the ratio of discoveries to dry holes is about 1:10 in the United States. Much research effort is being conducted in an attempt to improve this success ratio.

Once a discovery is made, additional wells are drilled nearby and, if successful, result in the development of a field. Whenever possible, the drilling of these development wells is guided by geologists' interpretations of the shape and characteristics of the reservoir rocks. These interpretations are based on data from rock samples, cores, and wireline logs from pertinent wells and from seismic data acquired throughout the area. It is important to accurately portray as many geologic factors as possible to best develop a field because each type of reservoir "behaves" in ways that can affect production. For example, a sandstone deposited as a beach ridge complex may contain streaks of oil-filled porosity that trend in directions quite differently from porous trends in a sandstone deposited in a tidal channel; a Silurian pinnacle reef contains porous carbonate rocks that differ markedly from those carbonates found in an oolite shoal.

Due to limits in technology, about 70% to 80% of the oil is left behind in the rocks after initial production is completed. Whenever possible, some of this remaining oil is forced out by injecting fluids, such as water, into the reservoir and pushing the oil toward producing wells. This "waterflood" method of recovery is used extensively in Illinois and typically enables about 50% of the original oil in place to be extracted (fig. 11).

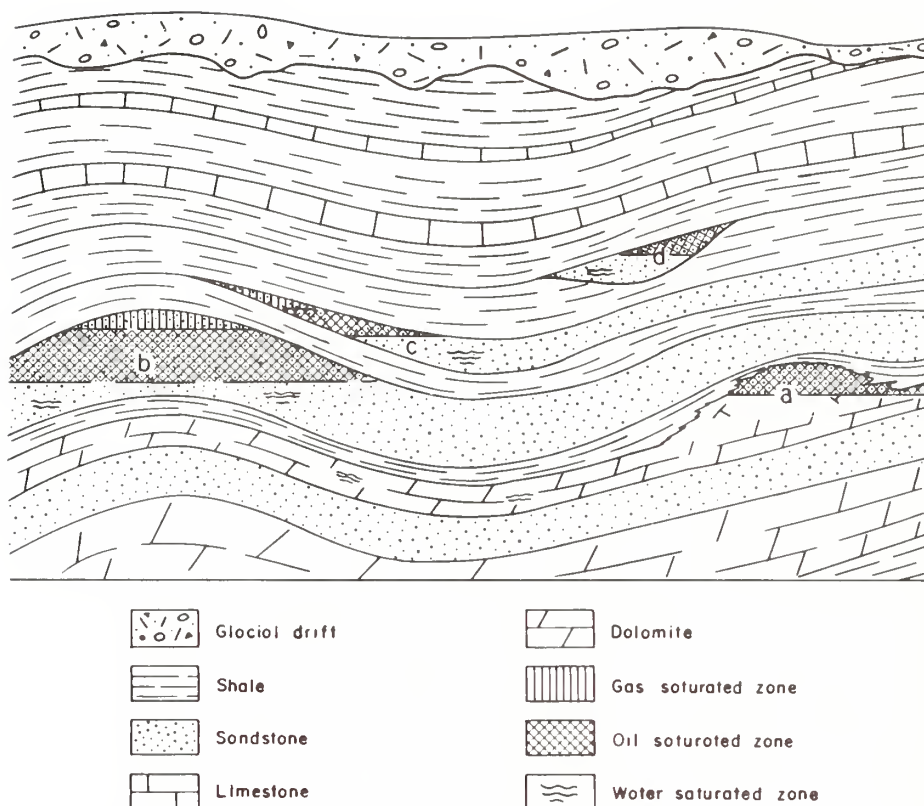
Some of the most important research dealing with oil and gas resources concerns designing better methods to extract oil from reservoirs. The U.S. Department of Energy, in conjunction with the State of Illinois, has been funding such research by the Oil and Gas Section at the Illinois State Geological Survey. This project, which involved ISGS staff who are experienced in geology, engineering, and geophysics, has been conducted with cooperation from the oil industry. This multidisciplinary study characterizes key reservoirs in Illinois and will ultimately detail improved and enhanced recovery techniques. By developing better drilling, completion, and extraction methods,



**Figure 9** Oil fields of the Illinois Basin.

it should be possible to improve recovery efficiency and consequently add significantly to the state's oil reserves. Additionally, improved recovery will improve the economics of exploring for oil and encourage exploration. Such improvements will be welcome news to some 60,000 people whose work revolves around the petroleum industry in Illinois.

Joan Crockett of the ISGS Oil and Gas Section has been studying the Tilden Oil Field. She has relied on the work of Baker and Carlisle (1992) for the following discussion. Sixty wells have produced about 5 million barrels of oil from the Silurian reef at Tilden since its discovery in 1951. This reef is 400 feet thick at its core, and more than 100 feet of structural closure is found on top of the Silurian rocks. Subsurface mapping of the shallow Pennsylvanian Herrin (No. 6) Coal identified a structurally higher locality in the area. Jet Oil Company drilled a test hole to evaluate the structure at Tilden and discovered oil in the Silurian at a depth of about 2,300 feet. Prior to the discovery at



**Figure 10** Places where oil is found in Illinois: (a) coral reefs, (b) anticlines, (c) pinchouts, and (d) channel sandstones.

Tilden, the company had drilled about 60 unsuccessful test holes in the region into similar structures hoping to discover a reef reservoir.

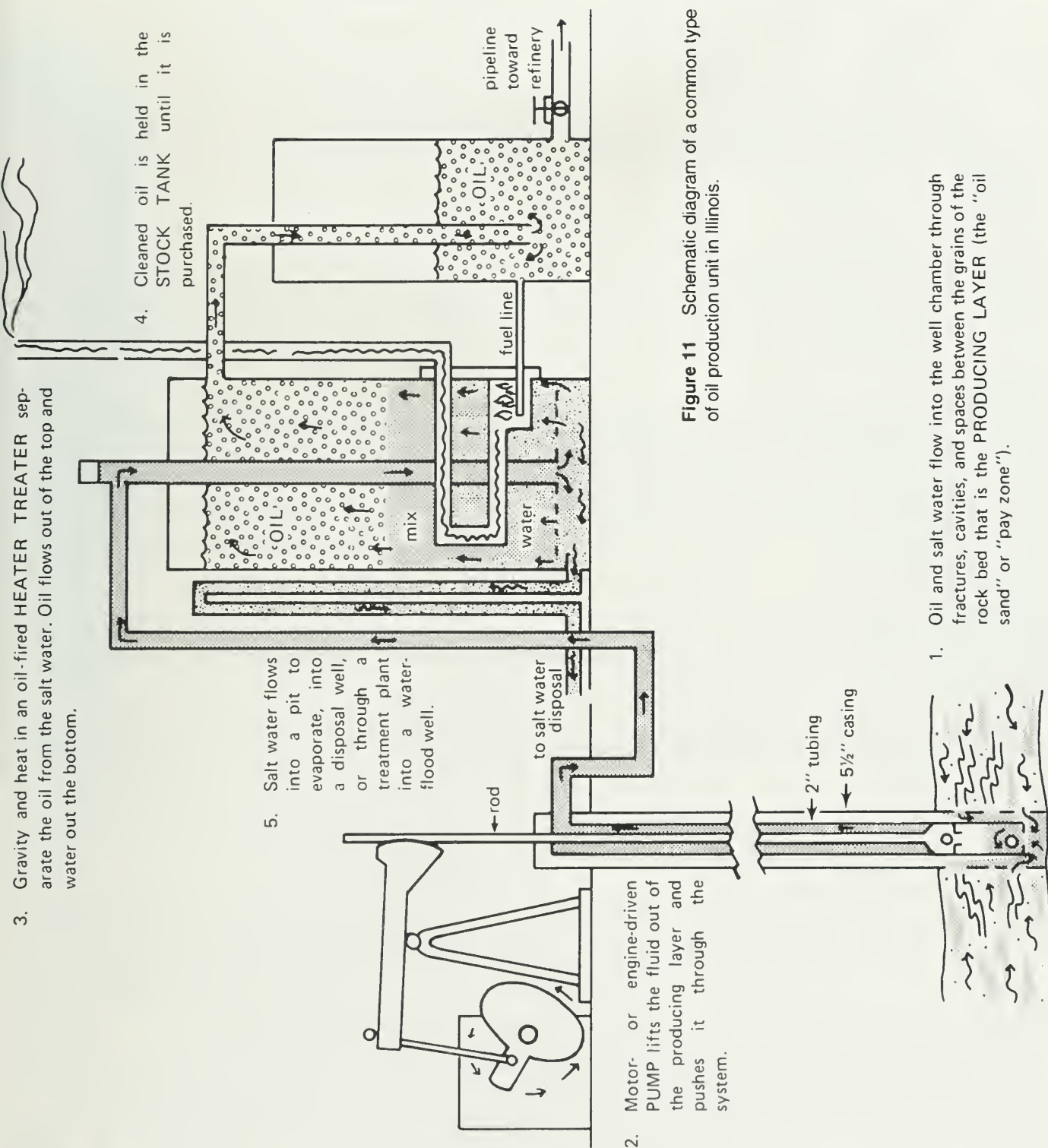
Structural domes may occur in younger rocks overlying reefs because the buried reef fossils form a rigid framework structure, whereas surrounding non-reef rocks in the Silurian are more readily compacted by burial. Rocks deposited above the reef appear to be draped over this rigid mass, forming the shallow structures observed on the subsurface maps.

Tilden's oil production was initially developed in the 1950s, as Jet Oil drilled wells that established the lateral limits of the field (shown on the route map). Most wells had oil in the upper 50 to 75 feet of the reef. A second phase of drilling took place in the late 1950s and in the 1960s, when wells were deepened about 50 feet. Over time, oil production at Tilden naturally declined as this portion of the reservoir was apparently depleted of oil.

In 1984, Jet Oil sold the field to Deminex U.S. Oil Company. Deminex evaluated the field and decided to drill new wells between the old wells (known as infill drilling) because they interpreted the original 20-acre well spacing was insufficient to drain the reservoir. The best new wells are located near the center of the structure.

Deminex also conducted a coordinated geologic and engineering study of the reservoir. They developed a model of a reef, where different reef-building organisms colonize different parts of the reservoir, growing in patches and on top of one another, and growing upwards to stay within the warm, nutrient-rich water. The colonies grow and are constantly being filled with carbonate mud at the same time as they grow. During storms, reef material is broken off and washed down the sides (flanks) of the reef, and the material is redeposited as broken chunks or conglomerate. The locations of patches of reef colonies and reef-rubble conglomerate are difficult to accurately predict





**Figure 11** Schematic diagram of a common type of oil production unit in Illinois.





between 20-acre or even 10-acre well spacing. This makes Tilden a complex, heterogeneous reservoir with multiple reservoir compartments.

The reef at Tilden was truncated (the top was eroded), and the uppermost Silurian rocks in the region were removed by erosion early in Devonian time, as the sea that once covered Illinois regressed (lowered.) This lowering of sea level exposed the reef to weathering processes that led in some cases to destruction of original porosity within the reservoir, and in some cases, to enhancement of porosity. At a later time in the Devonian, the sea returned to the area, and finally the organic-rich New Albany Shale was deposited over the region, forming both a hydrocarbon source rock and a capping seal for the reservoir. Mississippian and Pennsylvanian rocks were later deposited in the area, burying the reef.

Deminex interpreted that the reservoir at Tilden was not one continuous zone, but was composed of many small compartments that could be oil-bearing. The company began infill drilling and deepening. They also interpreted that some producing zones may have been overlooked in the past, or that some producing zones might benefit from being worked over using different techniques than had been used in the past. They tried perforating the zone, fracturing it, and introducing acid to clean and open up the rock and stimulate fluid flow.

Tilden is an interesting success story of improving oil recovery from an old field through use of new ideas, such as developing a clearer understanding of the reservoir, forming a more accurate model of the complex reservoir, recognizing that untapped deeper producing zones may be present, realizing that well spacing may have been inadequate to drain the reservoir, and applying new or different technologies to stimulate recovery. The successes at Tilden may be applicable to other, similar reservoirs in Illinois. This ultimately may be beneficial to both the economy in Illinois and to efficient recovery of an important natural energy resource.

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|      |      |                                                                                                                                                                                     |
|------|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0.0  | 5.1  | Leave Stop 2 and CONTINUE AHEAD (east).                                                                                                                                             |
| 0.2+ | 5.3+ | CAUTION: narrow concrete culvert.                                                                                                                                                   |
| 0.4  | 5.7+ | STOP: 1-way at T-intersection with blacktop. TURN RIGHT (south).                                                                                                                    |
| 0.5  | 6.2+ | T-road from left. TURN LEFT (east).                                                                                                                                                 |
| 0.4  | 6.6+ | PARK along the roadside as far to the right as you can safely. CAUTION: fast traffic and limited visibility because of the hill and dust. GATHER along the roadside for discussion. |

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**STOP 3** View and discussion of the Central Cleaning Plant for Zeigler Coal Company (from S edge SW SE SW NW Sec. 22, T4S, R5W, 3rd P.M., Randolph County; Tilden 7.5-Minute Quadrangle [38089B6]).

This modern Central Cleaning Plant processes coal from Mine No. 11, which is located nearly 1.5 miles to the east-southeast, and the Spartan Mine, which lies slightly more than 0.6 mile to the west-southwest. The cleaning plant has the capability of cleaning 1,000 tons of coal per hour. Both the Spartan mine, which opened in 1952, and Mine No. 11, which opened in 1977, are underground operations that produce coal from the Herrin (No. 6) Coal seam.

**Spartan Mine** was originally operated as the Bradbury Mine by the Midwest Utilities Coal Corporation from 1952 to 1957. Zeigler purchased the Bradbury mine in 1957 and changed the name to

Spartan. Its cumulative total production of coal from 1952-1991 amounted to 28,800,000 tons. The Spartan mine was idle in 1983 and 1984 and did not produce any coal.

Currently the Spartan Mine employs 146 miners and operates an average of 2.5 shifts daily. Daily production capacity from this mine averages 4,687 tons; 1,364,000 tons of coal in 1991.

The Herrin (No. 6) Coal averages 6.5 feet thick and is at a depth of 200 feet. The Spartan Mine is a slope mine with the main shaft inclined to the coal bed, along which men and materials enter the mine and coal is brought to the surface on a conveyor belt. Continuous miners are used to recover the coal at the Spartan Mine.

**Mine No. 11** has a cumulative total of coal of 14,800,000 tons from 1977-1991. Currently it employs 188 miners and operates three shifts daily. Daily production capacity from this mine averages 6,250 tons; 1,674,000 tons of coal in 1991.

The Herrin Coal averages 7 feet thick and is at a depth of 200 feet. Mine No. 11 is a combination slope and shaft. The main shaft is used to bring men and materials into the mine. The coal is transported via conveyor belt to the surface along the slope entrance and then overland to the central cleaning plant. Continuous miners also are used to recover the coal from Mine No. 11.

**General Geology** The Pennsylvanian Herrin Coal ranges from 6.5 to 7 feet in the two mines. The coal generally is directly overlain by one of three roof rocks of the Carbondale Formation: Breton Limestone Member, Energy Shale Member, and/or Anna Shale Member. The rocks under the coal generally consist of claystone. This area is famous for its marcasite "dollars," which are avidly collected by the miners because rockhounds pay good money for them. These round sand dollar shaped concretions, up to 3 inches in diameter, are actually composed of pyrite and are rarely found anywhere else in Illinois.

**Transportation** The majority of coal produced at the Spartan and No. 11 Mines is transported to its customers by the Union Pacific (UP) railroad. Some of the coal is carried by trains or trucks to river barges for delivery. In general, common carrier railroads normally require a minimum shipment of 10,000 tons per train for the lowest tariff charges. The tariff charges are based on a per ton charge. A standard bottom dump gondola railroad car holds 100 tons of coal. A unit train consists of a minimum of 100 gondola cars. A unit train consisting of 100 cars each carrying 100 tons transports 10,000 tons of coal.

**How much does a ton of bituminous coal weigh?** One ton of coal weighs 2,000 pounds. One ton of coal produces 26,200,000 Btu of energy. One ton of coal is equivalent to 4.52 barrels of oil. One ton of coal can produce 7,679 Kilowatt hours of electricity—enough electricity to light ten 100-watt light bulbs for a period of 320 days.

How much coal is in the ground? There is a standard formula for calculating the tonnage of coal beneath any property in a given area. The factors in the formula are the thickness of the coal in feet, the area occupied by the coal in acres, and a standard tonnage of 1,800 tons per acre of coal with a thickness of 1 foot. The 1,800 tons per acre-foot reflects a standard specific gravity of 1.32 for bituminous coal.







The formula is:

$$\text{thickness (in feet) x area (in acres) x tonnage} \frac{(1800 \text{ tons})}{(\text{acre-foot})} = \text{tons of coal}$$

Example:

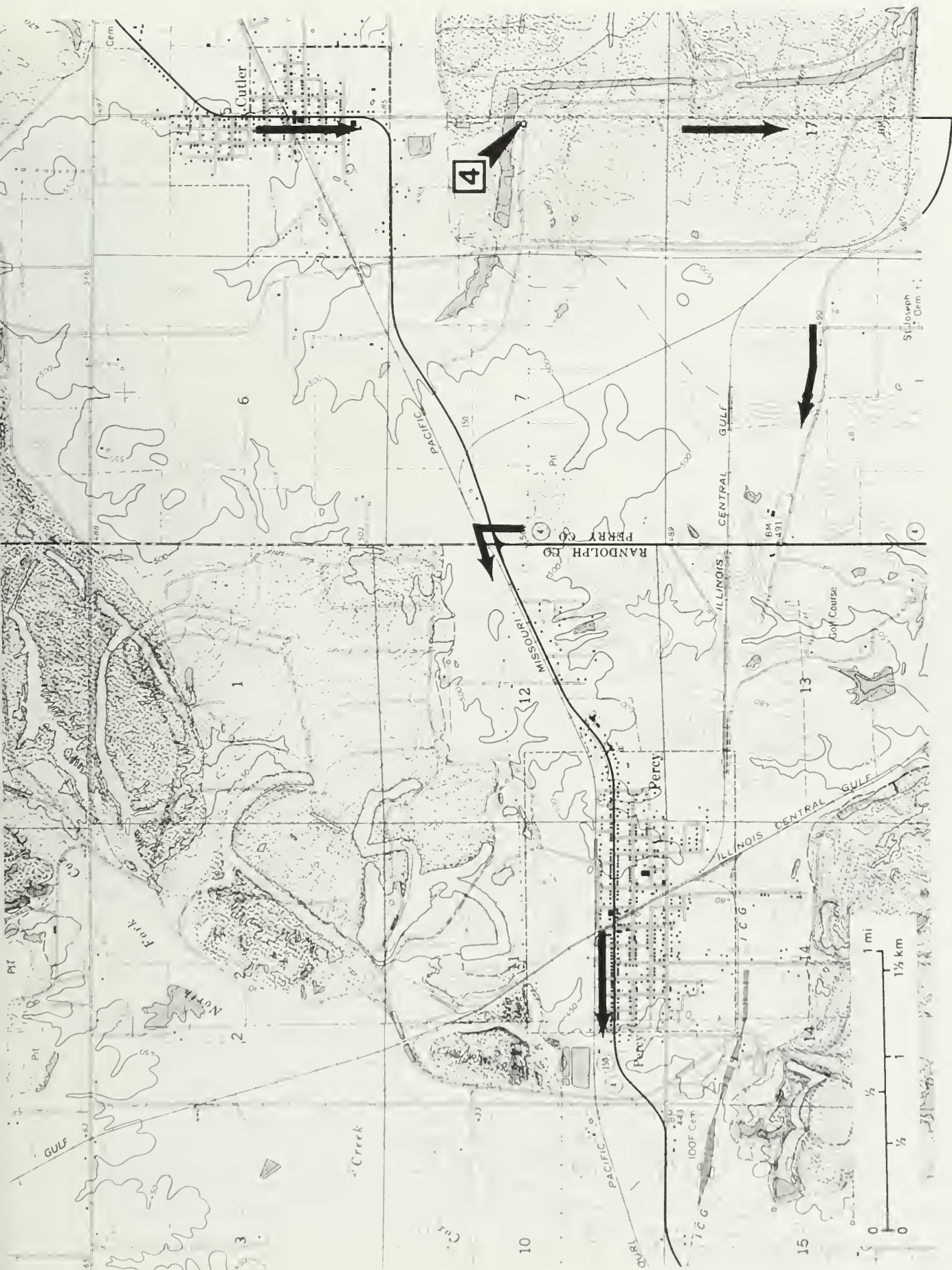
coal thickness = 6 feet

area = 250 acres

therefore, 6 x 250 x 1800 = 2,700,000 tons of coal in the ground.

---

|       |        |                                                                                                                                                                                                                                                                                                                                                              |
|-------|--------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0.0   | 6.6+   | Leave Stop 3 and CONTINUE AHEAD (east).                                                                                                                                                                                                                                                                                                                      |
| 0.3   | 6.9+   | The large silo to the right is for clean coal storage. Railroad coal cars slowly pass through the silo for loading. When the unit train is loaded, it reenters the mine service line as it heads to a distant power plant.                                                                                                                                   |
| 0.1   | 7.0+   | CAUTION: cross single unguarded Union Pacific (UP) RR track.                                                                                                                                                                                                                                                                                                 |
| 0.1   | 7.1+   | On the right is the entrance to Zeigler Coal Company's Central Cleaning Plant.                                                                                                                                                                                                                                                                               |
| 0.05- | 7.15+  | CAUTION: narrow concrete culvert.                                                                                                                                                                                                                                                                                                                            |
| 0.05+ | 7.25   | CAUTION: narrow concrete culvert over a headwater stream of Mary's River.                                                                                                                                                                                                                                                                                    |
| 0.6   | 7.85   | CAUTION: narrow concrete culvert over another headwater stream of Mary's River.                                                                                                                                                                                                                                                                              |
| 0.35  | 8.2    | STOP: 2-way at crossroad with SR 153. CAUTION: CONTINUE AHEAD (east). Township Road 63; 2,440 N/32.60 E.                                                                                                                                                                                                                                                     |
| 0.05+ | 8.25+  | View to right (south) of the elevated coal conveyor from Zeigler Coal Co. Mine No. 11 about 0.9 mile away. The structures at the end of the conveyor are the slope and other mine buildings. Notice that the general upland level is relatively even but very gently rolling in this area with a slight increase in altitude northward towards Coulterville. |
| 1.2   | 9.45+  | STOP: 2-way at crossroad. TURN RIGHT (south) on the countyline blacktop; after the turn, Randolph County is to the right and Perry County is to the left. The route closely follows the divide between Mary's River on the right and the Big Muddy River on the left.                                                                                        |
| 0.25+ | 9.7+   | On the left is an east-trending valley toward the Big Muddy River drainage.                                                                                                                                                                                                                                                                                  |
| 0.7+  | 10.45  | On the right is a west-trending valley toward the Mary's River drainage.                                                                                                                                                                                                                                                                                     |
| 0.8+  | 11.25+ | Pipeline crossing.                                                                                                                                                                                                                                                                                                                                           |
| 0.8+  | 12.1+  | Cross culvert over east-flowing tributary.                                                                                                                                                                                                                                                                                                                   |
| 0.75  | 12.85+ | The crest of this bedrock supported hill is about 0.1 mile to the left (east); 600+ feet msl. This is the highest hill in this vicinity. The closest comparable elevations are found 15 miles or so to the southwest near New Palestine, a couple of miles from the lunch stop. Note that the land surface is more                                           |



sharply rolling here and the streams are more deeply incised. Good panoramic views ahead.

|       |        |                                                                                                                                                                                                                                                                                                                                                                                                        |
|-------|--------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2.15+ | 15.0+  | STOP: 2-way at intersection, Randolph County 19.00N/34.00E, and SR 154. The area to the southeast is shown as the Sixmile Prairie on the Percy 7.5-Minute Quadrangle. Before surface mining in the area, the surface elevation sloped from 515 feet msl at this intersection to less than 440 feet msl near the southeast corner of the quadrangle. TURN LEFT (east) on SR 154 and enter Perry County. |
| 0.2   | 15.2+  | Slightly to the right in the distance and south of SR 154, several huge strip-ping shovels and dragline frames are silhouetted against the skyline. This area has been intensely surface mined. This same area was viewed from the hill at Stop 2 north of SR 154 on the Pinckneyville field trip in 1987.                                                                                             |
| 1.6+  | 16.8+  | Prepare to turn right.                                                                                                                                                                                                                                                                                                                                                                                 |
| 0.2   | 17.0+  | TURN RIGHT (south) toward Cutler on SR 150.                                                                                                                                                                                                                                                                                                                                                            |
| 0.15  | 17.15+ | The area to the left has been surface mined and is undergoing a reclamation program.                                                                                                                                                                                                                                                                                                                   |
| 1.5   | 18.65+ | The long lake to the right and the reclaimed area behind it to the west was part of Southwestern Illinois Corporation's Streamline Mine.                                                                                                                                                                                                                                                               |
| 1.95+ | 20.65+ | CAUTION: enter town of Cutler.                                                                                                                                                                                                                                                                                                                                                                         |
| 0.25  | 20.9+  | CAUTION: single guarded UP railroad track.                                                                                                                                                                                                                                                                                                                                                             |
| 0.3   | 21.2+  | CAUTION: LEAVE SR 150 at the east end of a curve and CONTINUE AHEAD STRAIGHT (south) on a blacktop road.                                                                                                                                                                                                                                                                                               |
| 0.55  | 21.75+ | PARK along the right shoulder as far off the road as you can safely and three or four car lengths north of the Kathleen Mine entrance. CAUTION: heavy, fast traffic at times. Do NOT block any of the gates or entrances along this side. STAY ON THE ROAD SHOULDER; Do NOT go across the ditch on either side—it is private property.                                                                 |

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**STOP 4** View Cutler Mining Company's Kathleen Mine and discuss Illinois' coal industry next to the mine entrance (E edge SE SE SE NW Sec. 8, T6S, R4W, 3rd P.M., Perry County; Percy 7.5-Minute Quadrangle [38089A5]).

This area south of Cutler was part of Arch of Illinois' famous Captain Mine that recovered coal from two seams, the Springfield (No. 5) and Herrin (No. 6). In 1966, the Captain Mine, which was then owned and operated by Southwestern Illinois Coal Corporation, was included on the ISGS Steeleville field trip. When the new owner, Arch of Illinois, ran out of reserves that could be surface mined, it decided to open a drift mine by tunneling horizontally into the Herrin Coal that was exposed in the south-facing wall of the last box-cut at a depth of 100-110 feet (Rigsby, 1992). It decided that a contractor would be commissioned under the name of Carter Coal Corporation to develop and operate the new Kathleen Mine.

The pit from the old strip mine site here was backfilled from below the Springfield Coal up to the Herrin Coal and the surface installations were operational by August 1984. Entries were driven into the coal, which was recovered by the use of electric-powered continuous miners and diesel shuttle cars. Early in 1985, the mine was operating two units, three shifts per day, 5 days per week with



one shift idled for maintenance. Coal from the mine is carried by a stacker belt to the top of the re-worked strip mine spoil pile on the south, where it is stockpiled and then transported by large off-highway trucks about 3 miles to the Arch of Illinois coal preparation plant, where it is cleaned and sold under contract.

In June 1986, Kathleen Mine closed after having recovered more than 858,000 tons of coal. Carter Coal Corporation ceased to be an entity at that time.

Kathleen Mine reopened in October of 1989 under the Cutler Mining Company, a wholly owned subsidiary of Arch Mineral Corporation, and returned to its six unit shifts per day. Since then, equipment has been continuously enlarged and upgraded with the result that the year to date average productivity rate is 1,600 tons of raw coal per shift. The mine currently has an annual production of 1.3 to 1.4 million tons of clean coal.

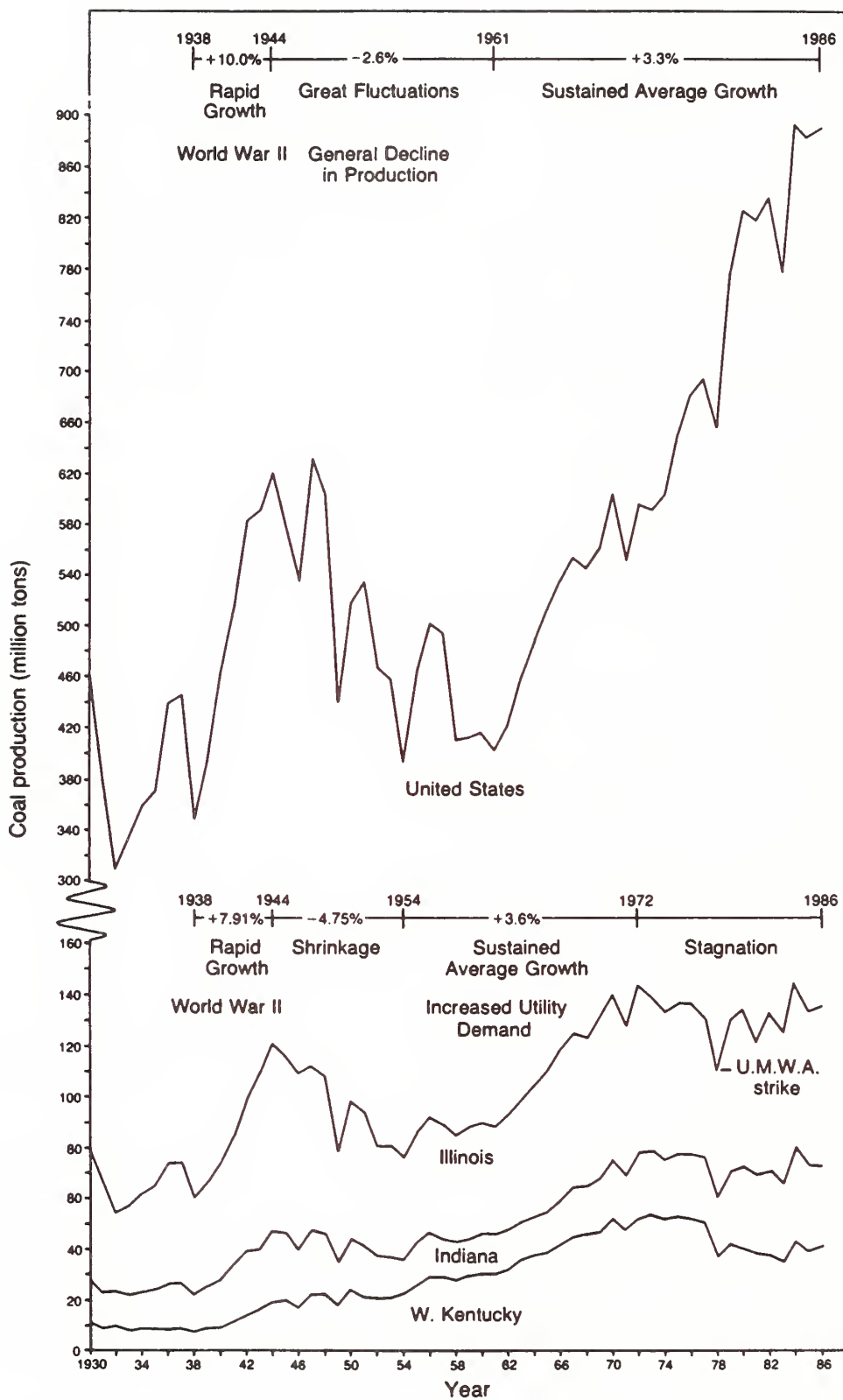
The following brief description of the south-facing highwall is modified from one made by ISGS geologists Steve Danner and Don Lumm in 1986:

- Glacial drift; 4 feet+
- Shale; 3 feet
- Coal; Danville (No. 7)(?); 1 feet
- Limestone; 1/4-1/2 feet
- Shale, brownish-gray; weathered; 12 feet
- Shale, dark gray; 1-1 1/2 feet
- Bankston Fork (Limestone; 1-1 1/2 feet over Shale; gray; 4 feet)
- Limestone; 1/2 feet
- Shale, dark gray; 3 feet
- Brereton Limestone, medium gray; massive; 5 feet
- Anna Shale, dark gray to black; 3 feet
- Herrin (No. 6) Coal; 6 feet

The following discussion has been updated for inclusion here (Reinertsen and Goodwin 1987). In recent years, more coal has been produced in Perry County than any other county in Illinois. In 1990, Perry County mines contributed about 11.3 million tons of coal valued at \$313.1 million, some 18.3% of the state's total production of about 61.7 million tons. All but about 1 million tons of Perry County coal was produced from surface strip mines.

Illinois coal is used in many areas of the eastern United States for generating electricity, manufacturing coke, and other industrial activities. In 1990, the last year for which such figures are available, 90% of all Illinois coal was sold to electric utility generating plants, 2% to coke plants manufacturing metallurgical coke, and 8% to industrial plants. Surprisingly, only 29% of Illinois coal sold to electric utilities was consumed within the state. Most out-of-state sales went to Missouri, Indiana, Florida and Georgia (Samson, in preparation). In recent years, coal mined in Illinois has been valued at about \$1.8 billion annually.

Much of the coal produced in Illinois has a high sulfur content (as much as 3% to 5%) that makes it expensive to burn while at the same time complying with the air pollution regulations promulgated by the various states and by the U.S. Environmental Protection Agency under the Clean Air Act and its amendments. The ISGS has been working hard for at least the last 15 years to find ways to remove the sulfur from Illinois coal before it is burned. Two techniques we have developed have shown considerable promise in laboratory tests, but it will be some time before those technologies can be moved into the market for further development and use by industry. For now, the installation of flue gas scrubbers at electric generating plants could make it possible to continue using Illinois coal despite its high sulfur content, if the price remains competitive.



**Figure 12** Trends in U.S. and Illinois Basin coal production, 1930-1986 (data adapted from U.S. Dept. of Energy, Bituminous Coal and Lignite Distribution) (from Bhagwat 1987).

Figure 12 shows that, from 1961 to 1986, the tonnage of coal mined in the United States increased an average of 3.3% per year. Low-sulfur western coals accounted for an increasing percentage of total U.S. coal production during the 1975-1985 period. By 1985, the western states, especially Colorado, Montana, New Mexico, Utah and Wyoming, accounted for 30.5% of total U.S. production, whereas 10 years earlier they accounted for only 15.5%. Over the 10 year period from 1975 to 1985, coal production outside the western states increased by about 13% (a total of 70 million tons), while production in the western states ballooned from 100 million tons in 1975 to 270 million tons in 1985. Figure 12 also shows that total production of coal from the Illinois Basin coal states (Illinois, Indiana, and western Kentucky) for the period 1975-1985 fluctuated around 130 million tons annually. The implication of these stagnant production levels is that Illinois Basin coal is losing its market position relative to other states; the region has not participated at all in the production increases of the 1975-1985 period. (Bhagwat 1987, p. 3-4).

Subhash Bhagwat, ISGS mineral economist, has shown that high production and delivery costs have hurt the marketability of Illinois Basin coal in recent years. When considered on the basis of delivered costs of heating value units (\$/Btu) some western coals, despite their lower heating values, cost about the same as coal from the Illinois Basin with higher heating value. Therefore, it is clear that reducing the sulfur content of Illinois Basin coal will not automatically ensure future sales in a highly cost-competitive market. Production costs also must be reduced (Bhagwat 1987, p. 14-16).

Many western coal seams are incredibly thick. Surface mines near Gillette, Wyoming, for example, produce from a coal bed that is more than 100 feet thick. These mining conditions contribute to average labor productivity rates (tons mined/person/hour worked) in some western states that are four to six times greater than the average in Illinois (Bhagwat 1987, p. 14). It should be borne in mind that most western coal is surface mined, whereas 64% of Illinois coal comes from underground mines. This fact contributes to the unfavorable comparisons with respect to labor productivity, since underground mining is inherently more labor intensive than surface mining. Illinois' surface minable coal resources are fairly limited in comparison to its deep minable resources. In the future, therefore, more and more coal will have to be mined underground in order to maintain the same annual production levels in Illinois. Perry County's minable coal resources having a high potential for surface mine development are estimated to be about 500 million tons or more, sufficient for about 35 to 40 more years of production at current rates. Thereafter, production will have to shift to underground mining of Perry County's estimated deep minable coal resources of 1.2 billion tons that have a high potential for development.

When a large enough area collapses in an underground coal mine, the land surface above the mine also subsides. Traditional room and pillar underground coal mining methods leave 40% to 60% of the available coal resource in the ground as supporting pillars to prevent the mine opening from ever collapsing. In fact, pillars sometimes do fail. In other cases, rather than failing, the weight of overlying rocks may push the pillar into the mine floor as relatively soft claystones that underlie the coal squeeze laterally out from under the pillar and into the adjacent vacant room areas. Thus, the room and pillar mining method, as presently practiced, does not infallibly prevent surface subsidence and, when used under undeveloped land areas, is unnecessarily wasteful of coal resources.

Unplanned subsidence of abandoned or inactive parts of room and pillar underground mines may damage homes and other structures and can form closed depressions that pond water in farm fields and reduce crop yields. With the cooperation of the Illinois Farm Bureau and the Illinois Coal Association, and with funds from the Illinois Coal Development Board, the U.S. Bureau of Mines and the U.S. Office of Surface Mining, the State Geological Survey is coordinating the Illinois Mine Subsidence Research Program. The twin goals of the research program are to develop mining procedures and guidelines that will allow Illinois mining companies to (1) better design room and pillar mines where they must be used to prevent surface subsidence, and (2) increase the efficiency of underground mining through the use of mechanized longwall or high-extraction retreat mining



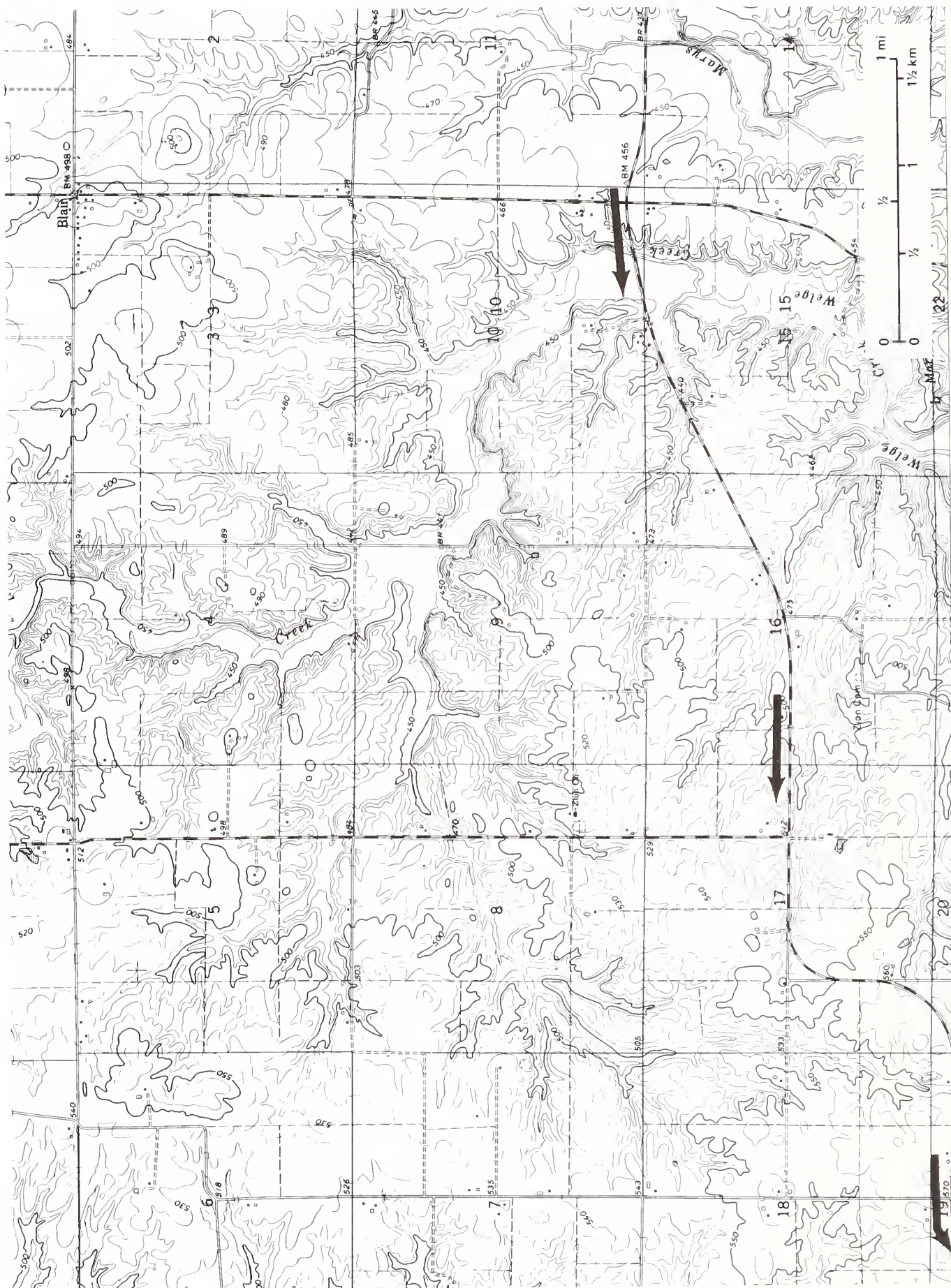
methods that substantially increase the amount of coal that is ultimately removed from the ground. High-extraction mining removes virtually all of the coal from the ground and allows the land surface to subside as the mine opening closes. Preliminary results of the ISGS-led program indicate that crop yields on farm land above high-extraction mined areas are reduced approximately 3% to 7% before taking any remedial measures. These effects seem to be small enough to be overcome by relatively inexpensive drainage improvements or land regrading, but studies of various mitigation techniques are only just beginning. It is expected that ways will be found for two of Illinois' major industries, coal mining and farming, to coexist harmoniously. As shown by the recent market trends, improved efficiency of underground mining is essential if the Illinois coal mining industry is to remain competitive.

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|       |        |                                                                                                                                                                                                                                                                                                                                                                                                   |
|-------|--------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0.0   | 21.75+ | Leave Stop 4 and CONTINUE AHEAD (south).                                                                                                                                                                                                                                                                                                                                                          |
| 1.2   | 22.95+ | CAUTION: large trucks; haulage road crossing.                                                                                                                                                                                                                                                                                                                                                     |
| 0.2   | 23.15+ | CAUTION: single unguarded railroad track.                                                                                                                                                                                                                                                                                                                                                         |
| 0.1+  | 23.25+ | STOP: 2-way at crossroads. TURN RIGHT (west).                                                                                                                                                                                                                                                                                                                                                     |
| 1.7+  | 24.95+ | STOP: 1-way at T-intersection with SR 4. NOTE: on the west side of the intersection is the Skuttle Inn Restaurant and Lounge. The north end of the Inn also contains a pro-shop for the adjoining golf course that is located above an abandoned underground mine. One or 2 holes on the golf course are situated on reclaimed surface mined land (Muckensturm 1973). TURN RIGHT (north) on SR 4. |
| 0.15+ | 25.15+ | CAUTION: single guarded Illinois Central (IC) railroad track.                                                                                                                                                                                                                                                                                                                                     |
| 0.8+  | 26.0+  | STOP: 4-way. TURN LEFT (west) on SRs 4 and 150.                                                                                                                                                                                                                                                                                                                                                   |
| 0.85  | 26.85+ | CAUTION: enter town of Percy.                                                                                                                                                                                                                                                                                                                                                                     |
| 0.6+  | 27.45+ | CAUTION: single guarded IC railroad track.                                                                                                                                                                                                                                                                                                                                                        |
| 0.35+ | 27.85+ | Leave town of Percy.                                                                                                                                                                                                                                                                                                                                                                              |
| 0.95  | 28.8   | CAUTION: single guarded IC railroad track.                                                                                                                                                                                                                                                                                                                                                        |
| 0.45+ | 29.25+ | CAUTION: enter town of Steeleville.                                                                                                                                                                                                                                                                                                                                                               |
| 1.2+  | 30.45+ | CAUTION: single guarded UP railroad crossing.                                                                                                                                                                                                                                                                                                                                                     |
| 0.45+ | 30.95  | Leave Steeleville.                                                                                                                                                                                                                                                                                                                                                                                |
| 0.1+  | 31.05+ | Cross Mary's River. Note how wide the valley is for the size of the present stream.                                                                                                                                                                                                                                                                                                               |
| 0.7+  | 31.75+ | Pipeline crossing.                                                                                                                                                                                                                                                                                                                                                                                |
| 0.45  | 32.2+  | STOP: 3-way at T-intersection, SRs 4 and 150. CONTINUE AHEAD (west) on SR 150.                                                                                                                                                                                                                                                                                                                    |
| 0.35  | 32.55+ | Prepare to turn right on Shawneetown Trail.                                                                                                                                                                                                                                                                                                                                                       |
| 0.1+  | 32.7+  | TURN RIGHT (north) and then left (west) on Shawneetown Trail.                                                                                                                                                                                                                                                                                                                                     |







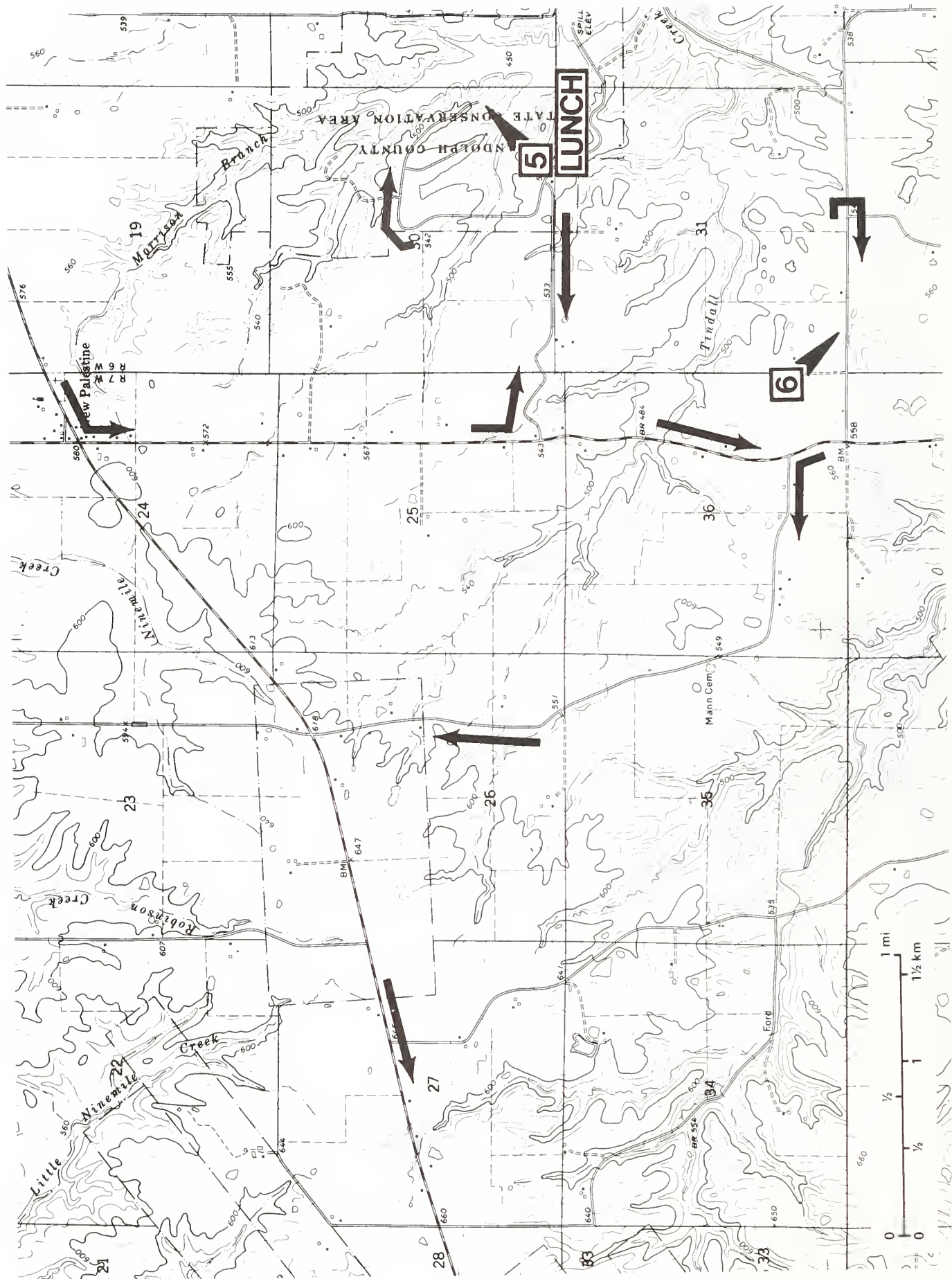


|       |        |                                                                                                                                                                                                                             |
|-------|--------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.3+  | 34.0+  | Cross Little Mary's River.                                                                                                                                                                                                  |
| 0.55+ | 34.55+ | CAUTION: Sparta crossroad. CONTINUE AHEAD (west).                                                                                                                                                                           |
| 0.15+ | 34.75  | Cross Welge Creek. The area to the right at about 2 o'clock looks like it has slumped, possibly due to the cattle wearing ruts across the slope. The ruts would have held more water, which made it more prone to slumping. |
| 2.15+ | 36.9+  | CAUTION: T-intersection from right; Schuline Road.                                                                                                                                                                          |
| 2.3   | 39.2+  | CAUTION: enter hamlet of New Palestine. Prepare to turn left.                                                                                                                                                               |
| 0.1+  | 39.35+ | TURN LEFT (south) toward the Randolph State Fish and Wildlife Area. This is the Baldwin Road; 12.60N/21.7E.                                                                                                                 |
| 1.5   | 40.85+ | Prepare to turn left.                                                                                                                                                                                                       |
| 0.1+  | 41.0   | TURN LEFT (east) at entrance road to Randolph State Fish and Wildlife Area.                                                                                                                                                 |
| 1.0   | 42.0   | STOP: 1-way at T-intersection. TURN LEFT (northwest and then north).                                                                                                                                                        |
| 0.7   | 42.7   | T-intersection from left; CONTINUE AHEAD STRAIGHT (east).                                                                                                                                                                   |
| 0.1   | 42.8   | T-intersection from right; CONTINUE AHEAD (east).                                                                                                                                                                           |
| 0.4   | 43.2   | Enter parking lot and PARK.                                                                                                                                                                                                 |

**STOP 5** Lunch and view of lake (N edge NE NE SE SE Sec. 30, T6S, R6W, 3rd P.M., Randolph County; Chester 7.5-Minute Quadrangle [37089H7]).

According to the park folder (IDOC, ca. 1991), land was purchased in 1958 and plans were developed for siting and building a 65-acre lake and spillway. The lake was completed in 1961 and since that time various recreational facilities have been added to attract the public. Good trails, camp sites, fishing spots, and wildlife of various kinds are found here.

|       |        |                                                                                                                                                                                                                                                                                  |
|-------|--------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0.0   | 43.2   | Leave Stop 5 and retrace route west to Baldwin Road.                                                                                                                                                                                                                             |
| 2.2   | 45.4   | STOP: 1-way at T-intersection of Baldwin Road. TURN LEFT (south).                                                                                                                                                                                                                |
| 0.35+ | 45.75+ | Cross Tindall Creek.                                                                                                                                                                                                                                                             |
| 0.6   | 46.35+ | Prepare to turn left.                                                                                                                                                                                                                                                            |
| 0.1+  | 46.5   | TURN LEFT (east) at T-intersection; 10.00N.                                                                                                                                                                                                                                      |
| 0.25  | 46.75  | Notice the sinkholes on both sides of the road in this area.                                                                                                                                                                                                                     |
| 0.1   | 46.85  | To the right are some areas that have underground drainage. Large cracks have opened up through the soil because of caving of the weak soil into underground crevices. The hole to the south is a large sinkhole. The road was constructed across a ridge between two sinkholes. |
| 0.35  | 47.2   | The road is across another ridge between sinkholes, perhaps at least partly manmade. The low area to the left is lower than that on the right. Quite a                                                                                                                           |



pond would have to develop before drainage would overtop the rim of the sinkhole to the left (north).

- |       |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|-------|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0.1   | 47.3  | CAUTION: make a U-TURN at the T-intersection from the south, 22.50E, and retrace the route. AFTER you turn, to the right (north) are two good sinkholes. The one in the foreground has some small trees in the bottom of it. They can only cultivate so close to it and so they've left part of it grassy and brushy to help control surface wash into the hole. A small rise in the land to the north of it separates it from another sinkhole slightly to the north and west of the one in the foreground. |
| 0.05  | 47.35 | North of the house is a water-filled sinkhole. The bottom is plugged with soil material.                                                                                                                                                                                                                                                                                                                                                                                                                     |
| 0.35+ | 47.7+ | PARK along the right shoulder as far off the road as you can safely. CAUTION: Beware of the poison ivy growing in the grass along the roadside.                                                                                                                                                                                                                                                                                                                                                              |

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**STOP 6** View sinkholes on both sides of the road (SWcor SE SW SW Sec. 31, T6S, R6W, 3rd P.M., Randolph County; Chester 7.5-Minute Quadrangle [37089H7]).

The upland in this vicinity is rather uneven because a number of sinkholes are scattered across it. The area is underlain by the upper Chesterian Menard Limestone of Mississippian age, which is about 100 feet thick here. Note that surface streams are almost totally absent within the sinkhole area. Rainwater charged with carbon dioxide from the atmosphere and humic acids from decaying vegetation percolates downward through the jointed limestone. The water gradually dissolves the limestone and enlarges the joints to form an interconnecting network of subterranean fissures. More and more of the surface drainage will be diverted into the subsurface and, if enough time passes without a change in these conditions, some of the fissures will enlarge into underground caverns.

Some sinkholes are purely solutional features and form by the enlargement of joints from the surface downward. Other sinkholes form where the roofs of caverns have collapsed. The result of this process is a rolling plain, pocked by numerous sinkholes and underlain by cavernous limestone. In some cases, open-jointed bedrock can be seen in the bottoms of some of the sinkholes. Others will have trees and/or shrubs in their lowest parts because of adequate soil moisture resulting from the partial plugging of the bottom. Still other sinks have water standing in them because their bottoms are plugged. Earthquakes or blasting may dislodge the plug and drain the sink. In some cases, depressions of several feet may suddenly develop anywhere in a field that is underlain by limestone when the bottoms of the plugged sinkholes open up. Undoubtedly, farming practices have been the cause of some of these.

Four conditions contribute to the development of sinkhole topography. First, there must be a relatively flat-lying limestone at or close to the surface. Second, the limestone should be dense, highly jointed, preferably thinly bedded, and not porous. If porous, rainwater will be absorbed and move through the whole body of rock rather than be concentrated along joints and bedding planes. Third, there must be major valleys entrenched below the uplands; these valleys act as outlets toward which the groundwater can move in the subsurface. Fourth, there must be ample rainfall. These conditions appear to be fulfilled to varying degrees in this area.

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- |       |       |                                                                                     |
|-------|-------|-------------------------------------------------------------------------------------|
| 0.0   | 47.7+ | Leave Stop 6 and CONTINUE AHEAD (west).                                             |
| 0.35+ | 48.1  | STOP: 1-way at T-intersection with Baldwin Road, 10.00N/28.80E. TURN RIGHT (north). |



|       |        |                                                                                                |
|-------|--------|------------------------------------------------------------------------------------------------|
| 0.2+  | 48.3+  | TURN LEFT (west) at T-intersection.                                                            |
| 2.3+  | 50.6+  | STOP: 2-way at Shawneetown Trail, 11.90N/20.70E. TURN LEFT (south-west).                       |
| 2.25+ | 52.9+  | STOP: 2-way at crossroad of Shawneetown Trail with SR 3; 14.00N/18.50E. CONTINUE AHEAD (west). |
| 0.35+ | 53.3+  | The field trip's highest elevation, 680+ feet msl is to the left about 200 feet from the road. |
| 0.35  | 53.65+ | Scenic view to the right (northwest); the distant skyline is Missouri.                         |
| 0.55  | 54.2+  | Start to descend steep hill.                                                                   |
| 0.25+ | 54.45+ | TURN RIGHT (north) at entrance to Fort Kaskaskia Historic Site.                                |
| 0.7+  | 55.15+ | PARK in lot next to the shelter and go to the overlook on the west side of it.                 |

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**STOP 7** View of the Mississippi River and discussion of the changes in the river's course (SW SE NE NE Sec. 31, T6S, R7W, 3rd P.M., Randolph County; Kaskaskia 7.5-Minute Quadrangle [37089H8]).

The ridge on which the park is situated is underlain by the Chesterian Menard Limestone of Mississippian age. This high ridge affords a magnificent view of the Mississippi Valley. Much of the following account is from an early park brochure (IDOC 1966):

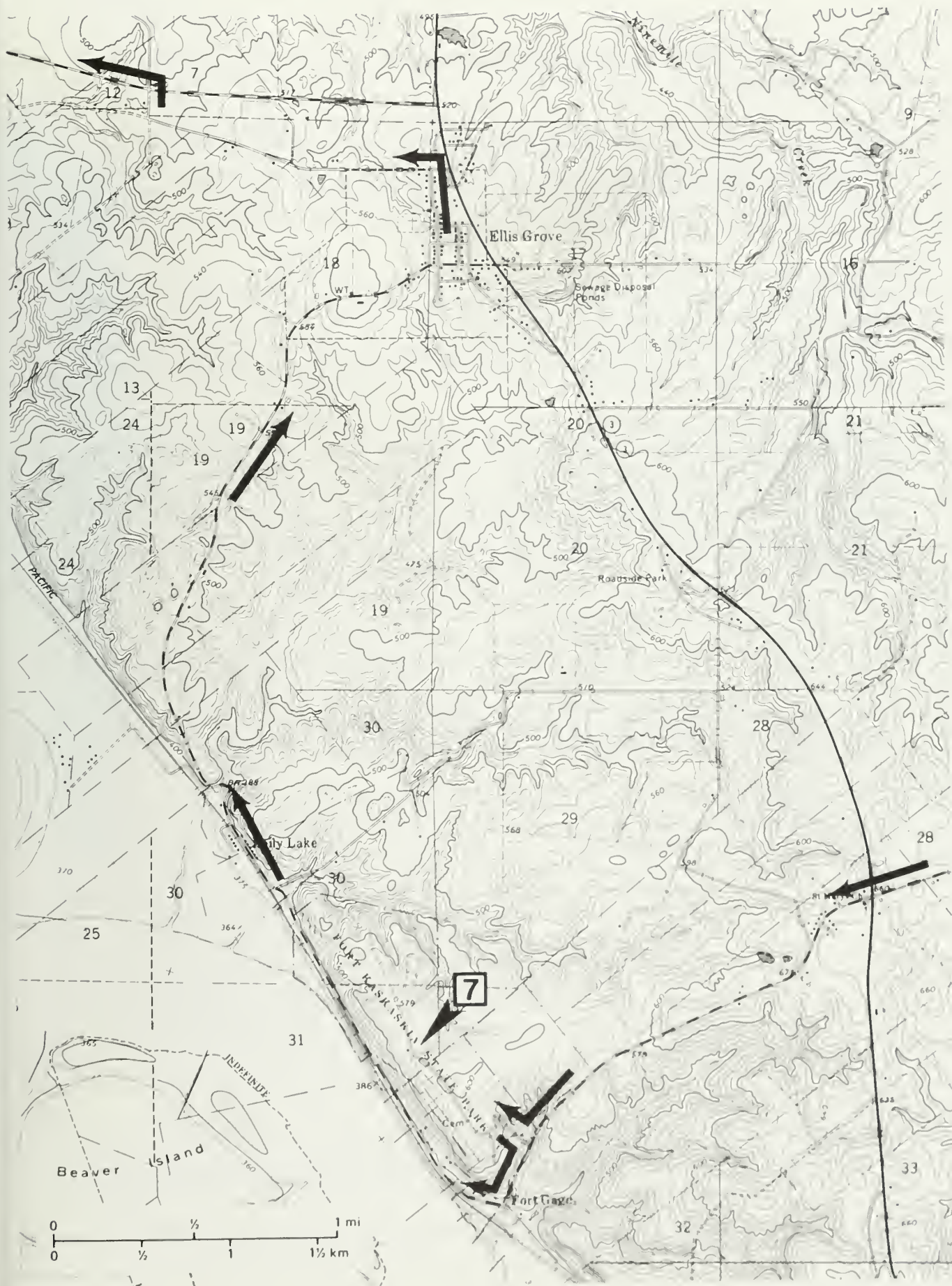
Fort Kaskaskia State Historic Site, comprising more than 200 acres in Randolph County, was incorporated into the Illinois Park System in 1927 as a memorial to early French and American pioneers who brought civilization to the Illinois wilderness.

The earthworks and foundations of the old fort still remain on the bluff overlooking the site of the first capitol of Illinois, Kaskaskia, across the Mississippi River on what is now Kaskaskia Island. Today, nothing remains of the town of Kaskaskia, once the "commercial queen of the west," the seat of government during Illinois territorial days, and one of the principal French settlements.

Founded in 1703, Kaskaskia soon attracted a sizable number of settlers and traders. For a number of years it was protected by a wooden stockade, but the structure was designed for Indian defense only. During the French and Indian War, during the early 1700s, the inhabitants, fearing a British attack, petitioned for a fort, offering to furnish the materials. Their petition was granted and Fort Kaskaskia, made of heavy palisades, was built on the bluff above and across from the town. There it stood until 1776, when the townspeople destroyed it rather than allow it to be occupied by the British, to whom control had passed in 1775.

In 1778, George Rogers Clark took Kaskaskia and Ft. Gage from the British. The stone fort was one of the Jesuit buildings that had been turned into a barracks upon the suppression of the Jesuit Order. Thereupon, the Illinois country became a county of Virginia. But, with the end of the American Revolution, local government broke down and Kaskaskia was plunged into anarchy. In 1784, John Dodge, a Connecticut adventurer, and a group of desperadoes seized and fortified Fort Kaskaskia, and terrorized the villagers for several years.

In 1787, Illinois became part of the Northwest Territory under the government of the United States. In 1809, Kaskaskia became the capitol of the Illinois Territory, created in that year, and in 1818 reached the peak of its importance, becoming the capitol of the new State of Illinois. Three rooms in the home of Dr. George Fisher were rented for use by the State, and there the first session of





the General Assembly was held. In 1820, however, the capitol was moved to Vandalia, and Kaskaskia's decline began.

A Mississippi River flood nearly destroyed the town in 1844, but a flood in 1881 did complete the destruction; remnants of the site were washed away by 1910. Commemorating the memory of the vanished town, the State of Illinois has built on Kaskaskia Island the Kaskaskia Bell State Memorial where hangs the "Liberty Bell of the West." This 650-pound bell was cast in France in 1741 and given by King Louis XV to the Kaskaskia church. This bell rang out lustily on the Fourth of July night in 1778 when George Rogers Clark captured the town.

Before the Pleistocene Epoch and the glacial advances, the Ozark Peneplain was uplifted several hundred feet and renewed erosion carved out the present network of streams and valleys. The Mississippi, probably born during the late Tertiary Period, was able to maintain its existence during this period of slow uplift by cutting its valley deeply into the peneplain. The great torrents of glacial melt-water that flowed down the Mississippi River during the Ice Age certainly contributed to the widening and the deepening of the valley.

The large and powerful Mississippi River has always been a romantic feature in the history of the exploration and settlement of the American West. When early settlers came to this region and settled at Kaskaskia, the Mississippi River flowed in a wide arc around the west side of present-day Kaskaskia Island. When the flood waters receded from the 1881 flood, the river has assumed a new channel on the east side of the valley where the town had been. Because the boundary between Illinois and Missouri had been established before the channel shift, Kaskaskia Island is a part of Illinois.

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|-------|--------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0.0   | 55.15+ | Leave Stop 7 and RETRACE ROUTE to the park entrance.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| 0.1   | 55.25+ | Garrison Hill Cemetery is to the right. In 1891, before the area was a park, the state moved the pioneer burials from three lowland cemeteries at the confluence of the Kaskaskia and Mississippi Rivers to this site when the old cemeteries were endangered by floods. A monument to the pioneers was erected in the center of the cemetery, which is now in the park.                                                                                                                                                                                                                                                                                                                 |
| 0.6+  | 55.85+ | STOP: 1-way at T-intersection. TURN RIGHT (west) down hill.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| 0.2+  | 56.1+  | CAUTION: YIELD at T-intersection. TURN RIGHT (north).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| 0.05+ | 56.15+ | To the right is the home of Pierre Menard, a State Historic Site. The home, built in 1802, is the finest example of Southern French Colonial architecture in the central part of the Mississippi Valley, according to a site brochure (IDOC 1976). It is now often called "The Mt. Vernon of the West." Menard, born in 1766, signed on with a trading expedition to the Illinois country when he was 15 years old. By the time he was 24, he had established his own trading business. He was the presiding officer of the first Territorial Legislature and first Lieutenant Governor of Illinois in 1818. He died here in his home in 1844, at the age of 78. CONTINUE AHEAD (north). |
| 1.4+  | 57.65+ | CAUTION: hamlet of Riley Lake. CONTINUE AHEAD.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 0.3   | 57.95+ | Cross creek; stay on blacktop and ascend hill.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 0.6   | 58.55+ | Three sinkholes occur for next 0.15 mile 200 to 400 feet to the left (north) of the road.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 0.35  | 58.9+  | A sinkhole is located to the left (north) about 100 feet from the road.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |



|       |        |                                                                                                                                                                                           |
|-------|--------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0.9   | 59.8+  | To the right the hill slope has been terraced to control erosion.                                                                                                                         |
| 0.1   | 59.9+  | Enter village of Ellis Grove.                                                                                                                                                             |
| 0.4+  | 60.35  | STOP: 4-way at crossroad. TURN LEFT (north).                                                                                                                                              |
| 0.05+ | 60.4+  | CAUTION: business district. Northward, the street jogs left and then right.                                                                                                               |
| 0.25+ | 60.65+ | STOP: 3-way at T-intersection. TURN LEFT (west).                                                                                                                                          |
| 0.15+ | 60.85+ | CAUTION: narrow culvert.                                                                                                                                                                  |
| 0.85+ | 61.7+  | TURN RIGHT (north) at intersection; 13.90N/15.90E.                                                                                                                                        |
| 0.1   | 61.8+  | STOP: 2-way at crossroad; 14.20N/16.00E. TURN LEFT (west).                                                                                                                                |
| 0.65+ | 62.5+  | Cross small sinkhole tract extending from 600 feet south of road northward for 0.7 mile.                                                                                                  |
| 0.25+ | 62.75+ | Descend the east wall of the Kaskaskia Valley next to its confluence with the Mississippi Valley.                                                                                         |
| 0.35+ | 63.15+ | Cross over single track Missouri-Illinois (M-I) railroad.                                                                                                                                 |
| 0.3+  | 63.45+ | Cross the Kaskaskia River bridge. Several years ago the river was straightened and deepened to facilitate barge traffic from the coal fields of northern Randolph and St. Clair Counties. |
| 0.6+  | 64.1+  | PARK along the shoulder as far off the road as you safely can. Do NOT block any lanes or gates. CAUTION: fast traffic.                                                                    |

**STOP 8** View Pleistocene deposits overlying Mississippian Chesterian strata in the abandoned Root Quarry (Latitude 38°0'59" N; Longitude 89°58'4" W, Randolph County; Evansville 7.5-Minute Quadrangle [38089A8]).

The Mississippian strata exposed in this abandoned quarry are parts of the upper Chesterian Hardinsburg and Haney Formations. These rocks occur stratigraphically below the Menard Limestone that underlies Stops 6 and 7 (note figure 2). The section exposed here follows:

Hardinsburg Formation - shale, greenish with thin greenish siltstone beds and two thin limestone beds; 6 feet.

Haney Limestone - limestone, light gray, very oolitic, fossiliferous in upper part; 29 feet.

Limestone, yellowish brown, fine grained, dense, dolomitic, argillaceous; 1 foot.

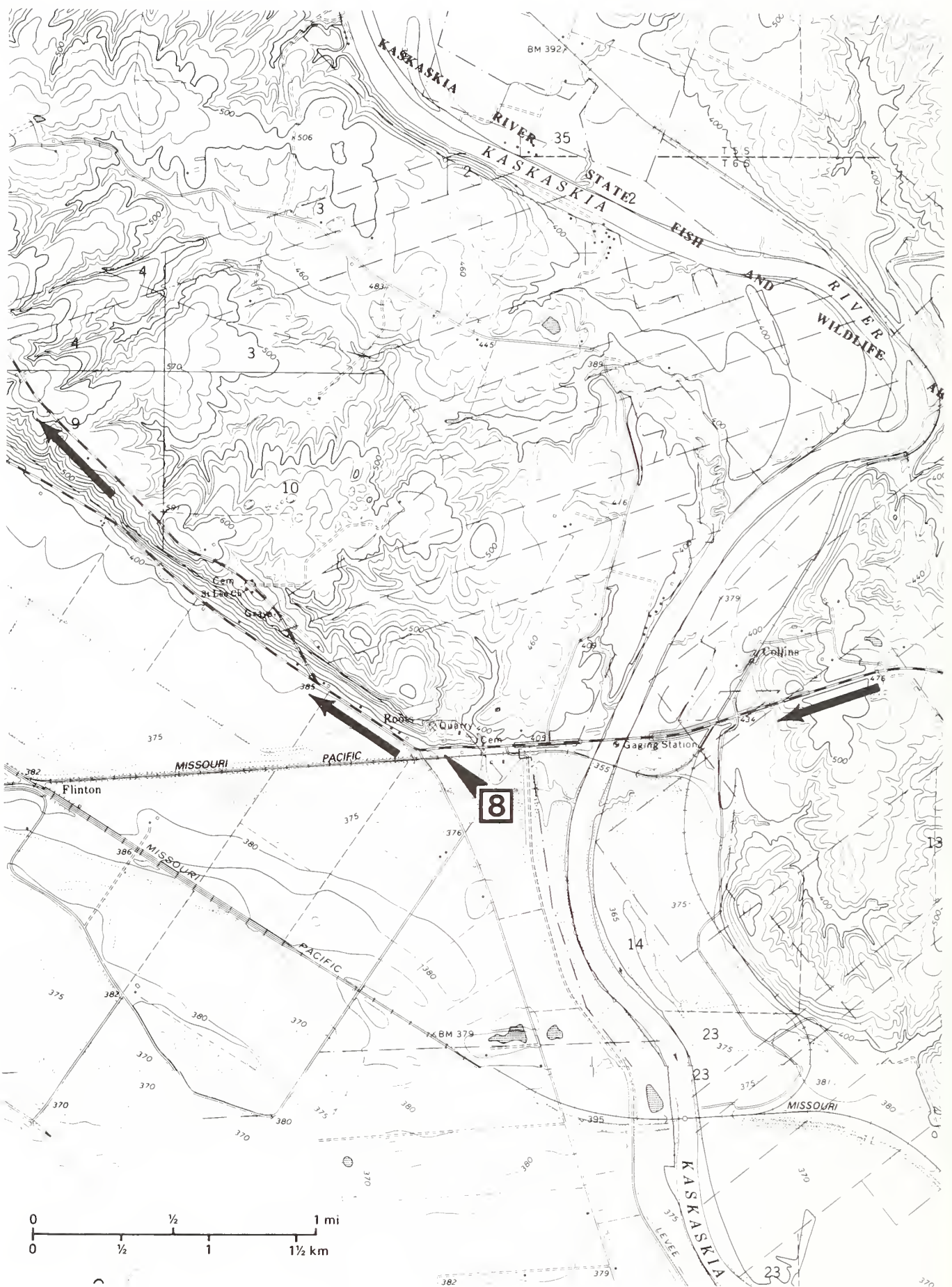
Limestone, light gray to gray, partly oolitic, fossiliferous; 5 feet.

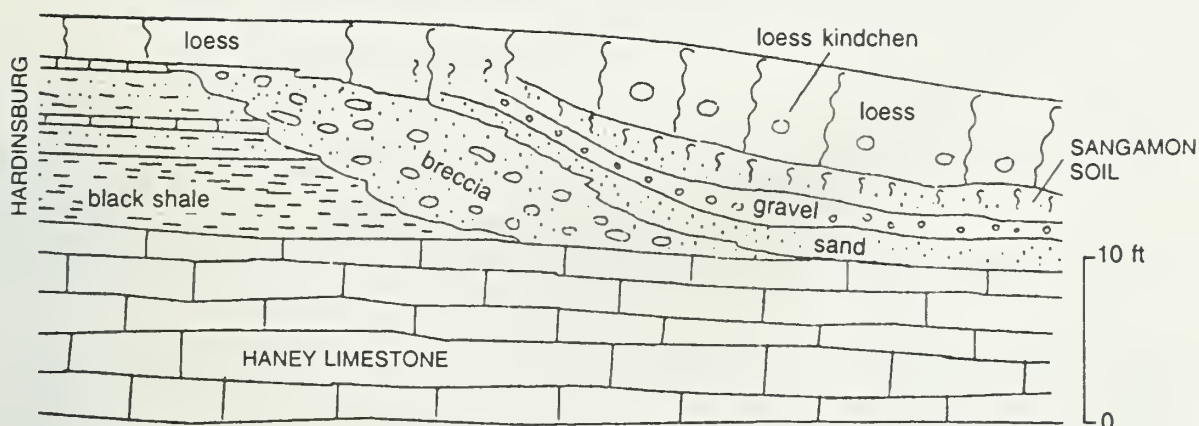
Limestone, gray, mostly medium fossil fragments; 7 feet.

Quarry floor.

In the Sparta field trip area, the Illinoian glacier advanced to the Mississippi River bluffs, possibly even crossing the river. The exact position of the ice margin is unknown because only scattered remnants of glacial till occur on the upland surface.

The Pleistocene section at the Root Quarry is illustrated on the following page.





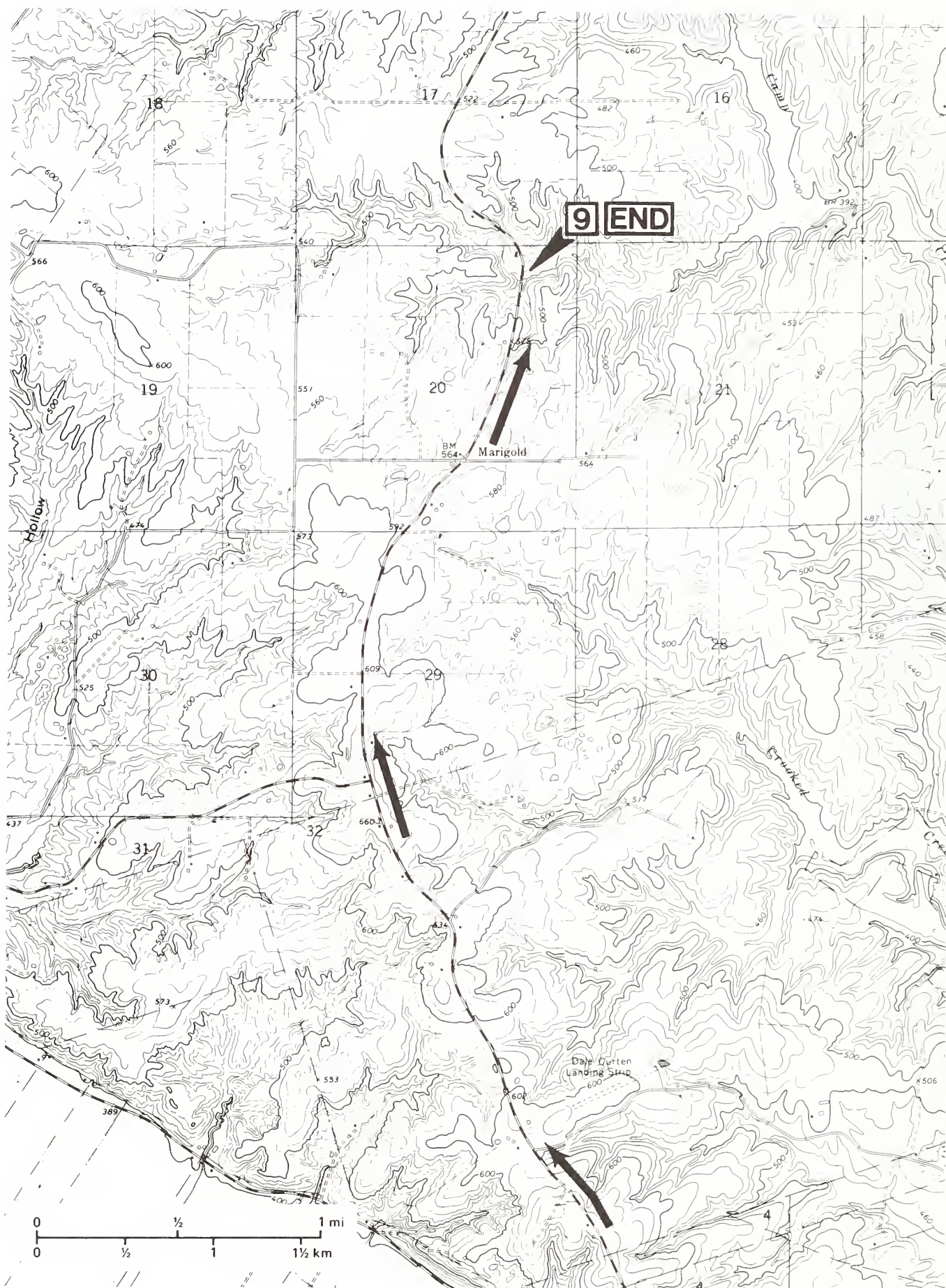
**Figure 13** Pleistocene section at Root Quarry.

During Illinoian time when the Kaskaskia River flowed at a level about 100 feet higher than at present, it deposited the sand and gravel outwash that can be seen here. The limestone breccia below the gravel is a slump deposit, formed when the river undercut its bank, collapsing it. A soil profile, formed during Sangamonian time, is developed in the outwash. Wisconsin Peoria Loess overlies the Sangamon Soil.

Of particular interest here are the small, irregular concretions that occur in the lower half of the loess deposit. These concretions, called "loess kindchen" (children of the loess), are formed by differential cementation of the loess by calcium carbonate, which has been leached from above and then carried downward by percolating groundwater. Some of the concretions rattle when shaken and are called "klopfenstein" or rattle stones.

|       |        |                                                                                                                                                        |
|-------|--------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0.0   | 64.1+  | Leave Stop 8 and CONTINUE AHEAD (west).                                                                                                                |
| 0.1   | 64.2+  | CURVE RIGHT (northwest).                                                                                                                               |
| 0.4+  | 64.65  | BEAR RIGHT (north-northwest) at R-intersection and ascend steep hill up the bluff. Limestone is exposed on the right a short distance up in the woods. |
| 0.2   | 64.85+ | Vertical exposures of loess here are at least 18 feet thick.                                                                                           |
| 0.05+ | 64.9+  | To the left, the small mound with a large cedar tree is the grave of Dr. George Fisher, an early physician and politician in Randolph County.          |
| 0.1+  | 65.05+ | St. Leo's Church on the left.                                                                                                                          |
| 1.25  | 66.3+  | Scenic view to right (east and northeast).                                                                                                             |
| 0.05+ | 66.35+ | Scenic view to left (southwest) toward Missouri.                                                                                                       |
| 0.05+ | 66.45+ | Panoramic view to right (east and northeast).                                                                                                          |
| 1.15+ | 67.6+  | To the right at about 1:15 o'clock (northeast) is Illinois Power Company's Baldwin Power Plant about 13.5 miles away.                                  |
| 1.95  | 69.55+ | Crossroad; 18.30N/11.5E. CONTINUE AHEAD (north).                                                                                                       |





0.65+      70.25      PARK along shoulder as far off as you safely can. Do NOT stop on the bridge. YOU MUST HAVE PERMISSION to enter this property. Do NOT climb fences. CLOSE all gates.

---

**STOP 9** View Mississippian Chesterian strata on both sides of the bridge along the creek (S 1/2 NW SE NE Sec. 20, T5S, R8W, 3rd P.M., Randolph County; Prairie Du Rocher 7.5-Minute Quad-range [38090A1]).

Upper Chesterian strata of Mississippian age are exposed in the creek on both sides of the road. Stratigraphically, these strata occur below the Haney Limestone exposed at Stop 8.

The Beech Creek Limestone, which was deposited some 336 million years ago, is the oldest bed-rock exposed on the Sparta field trip. It is the dark, sandy limestone which is exposed in the creek bed on the west side of the bridge. Although less than 10 feet thick in this vicinity, only a couple of feet are exposed here. It is as much as 35 to 40 feet thick in northern central Illinois. The Beech Creek, commonly called the "Barlow Lime" in the oil industry, is very persistent and widely recognized as an horizon in compiling structure contour maps of the Illinois Basin.

The Fraileys Shale consists of interbedded shales and argillaceous limestones in the stream bank east of the bridge. It is quite fossiliferous here. Although it may be 80 to 100 feet thick in southern Illinois, it is slightly more than 60 feet thick in this area. Compare the fossils you collect with the illustrations of Mississippian fossils in the back of the guidebook.

This is the end of the trip. CONTINUE AHEAD (north and east) for 3 1/4 miles to Ruma and SR 3.

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## GLOSSARY

Several sources were used for the definitions, but the main reference is the *Glossary of Geology*, edited by Robert L. Bates and Julie A. Jackson (American Geological Institute, 1987).

**Age** — An interval of geologic time; a division of an epoch.

**Alluviated valley** — One that has been at least partly filled with sand, silt, and mud by flowing water.

**Alluvium** — A general term for clay, silt, sand, gravel, or similar unconsolidated detrital material deposited during comparatively recent time by a stream or other body of running water as a sorted or semisorted sediment in the bed of a stream or on its floodplain or delta.

**Anticline** — A convex upward rock fold in which strata have been bent into an arch; the strata on each side of the core of the arch are inclined in opposite directions away from the axis or crest; the core contains rocks older than those on the perimeter of the structure.

**Aquifer** — A geologic formation that is water-bearing and transmits water from one point to another.

**Argillaceous** — Largely composed of clay-sized particles or clay minerals.

**Bed** — A naturally occurring layer of earth material of relatively greater horizontal than vertical extent; it is characterized by a change in physical properties from overlying and underlying materials. It also is the ground upon which any body of water rests or has rested; the land covered by the waters of a stream, lake, or ocean; or the bottom of a watercourse or stream channel.

**Bedrock** — The solid rock underlying the unconsolidated (non-indurated) surface materials such as soil, sand, gravel, and glacial till.

**Bedrock valley** — A drainageway eroded into the solid bedrock beneath the surface materials. It may be completely filled with unconsolidated (non-indurated) materials and hidden from view.

**Braided stream** — A low gradient, low volume stream flowing through an intricate network of interlacing shallow channels that repeatedly merge and divide, and are separated from each other by branch islands or channel bars. Such a stream may be incapable of carrying all of its load.

**Calcarene** — Limestone composed of sand-sized grains consisting of more or less worn shell fragments or pieces of older limestone; a clastic limestone.

**Calcareous** — Containing calcium carbonate ( $\text{CaCO}_3$ ); limy.

**Calcite** — A common rock-forming mineral consisting of  $\text{CaCO}_3$ ; it may be white, colorless, or pale shades of gray, yellow, and blue; it has perfect rhombohedral cleavage, appears vitreous, and has a hardness of 3 on the Mohs' scale; it effervesces (fizzes) readily in cold dilute hydrochloric acid. It is the principal constituent of limestone.

**Chert** — Silicon dioxide ( $\text{SiO}_2$ ); a compact, massive rock composed of minute particles of quartz and/or chalcedony; it is similar to flint but lighter in color.

**Clastic** — Fragmental rock composed of detritus, including broken organic hard parts as well as rock substances of any sort.

**Closure** — The difference in altitude between the crest of a dome or anticline and the lowest contour that completely surrounds it.

**Concretion** — A hard, compact, commonly rounded (but also disk-shaped or irregular in form) mass or aggregate of mineral matter; usually of a composition widely different from that of the rock in which it is found.

**Crystalline** — Said of a rock consisting wholly of crystals or fragments of crystals; esp. said of an igneous rock developed through cooling from a molten state and containing no glass, or of a metamorphic rock that has undergone recrystallization.

**Delta** — A low, nearly flat, alluvial land deposited at or near the mouth of a river where it enters a body of standing water; commonly a triangular or fan-shaped plain sometimes extending beyond the general trend of the coastline.

**Detritus** — Material produced by mechanical disintegration.

**Disconformity** — An *unconformity* marked by a distinct erosion-produced, irregular, uneven surface of appreciable relief between parallel strata below and above the break; sometimes represents a considerable interval of nondeposition.

**Dolomite** — A mineral, calcium-magnesium carbonate ( $\text{CaMg}(\text{CO}_3)_2$ ); applied to those sedimentary rocks that are composed largely of the mineral dolomite; it is also precipitated

- directly from seawater. It is white, colorless, or tinged yellow, brown, pink, or gray, and has perfect rhombohedral cleavage; it appears pearly to vitreous, and effervesces feebly in cold dilute hydrochloric acid.
- Drift* — All rock material transported by a glacier and deposited either directly by the ice or reworked and deposited by meltwater streams and/or the wind.
- End moraine* — A ridge-like or series of ridge-like accumulations of drift that develop along the margin of an actively flowing glacier at any given time; a moraine that has been deposited at the lower or outer end of a glacier.
- Eon* — The largest division of geologic time; it consists of two or more eras.
- Epoch* — An interval of geologic time; a division of a period.
- Era* — A unit of geologic time that is next in magnitude beneath an eon; consists of two or more periods.
- Fault* — A fracture surface or zone in earth materials along which there has been vertical and/or horizontal displacement or movement of the strata on both sides relative to one another.
- Ferruginous* — Pertaining to or containing iron, e.g., a sandstone that is cemented with iron oxide.
- Fissile* — Capable of being easily split along closely spaced planes; laminae generally less than 2 millimeters thick.
- Floodplain* — The surface or strip of relatively smooth land that lies adjacent to a stream channel and has been produced by stream erosion and deposition; the area covered with water when the stream overflows its banks at times of high water; it is built of alluvium carried by the stream during floods and deposited in the sluggish water beyond the influence of the swiftest current.
- Fluvial* — Of or pertaining to a river or rivers.
- Fluviolacustrine* — Pertains to sedimentation partly in lake water and partly in streams, or to sediments deposited under alternating or overlapping lacustrine and fluvial conditions.
- Formation* — The basic rock unit distinctive enough to be readily recognizable in the field and widespread and thick enough to be plotted on a map. It describes the strata, such as limestone, sandstone, shale, or combinations of these and other rock types; formations have formal names, such as Joliet Formation or St. Louis Limestone (Formation), which are usually derived from geographic localities.
- Geologic column* — a chart that shows the subdivisions of part or all of geologic time or the sequence of stratigraphic units (oldest at the bottom and youngest at the top) of a given place or region.
- Geophysics* — Study of the earth by quantitative physical methods.
- Glacier* — A large, slow-moving mass of ice at least in part on land.
- Graben* — An elongate, relatively depressed crustal unit or block that is bounded by faults on its long sides. It is a structural form that may or may not be geomorphologically expressed as a rift valley.
- Gradient* — A part of a surface feature of the earth that slopes upward or downward; a slope, as of a stream channel or of a land surface.
- Ground moraine* — A sheet-like accumulation of glacial drift, principally till, deposited beneath a glacier to form an extensive area of low relief devoid of transverse linear features.
- Groundwater* — Water that is present below the ground surface in the soil and rocks of the earth's outer crust.
- Group* — A geologic rock unit consisting of two or more formations.
- Hydrogeology* — The science that deals with subsurface waters and related geologic aspects of surface waters.
- Ice sheet* — A glacier of considerable thickness and more than 50,000 square kilometers in area, forming a continuous cover of ice and snow over a land surface...and not confined by the underlying topography; a *continental glacier*.
- Igneous* — Said of a rock or mineral that solidified from molten or partly molten material, i.e., from magma.
- Indurated* — A compact rock or soil hardened by the action of pressure, cementation, and especially heat.
- Joint* — A fracture or crack in rocks along which there has been no movement of the opposing sides.



*Lacustrine* — Produced by or belonging to a lake.

*Laurasia* — A combination of Laurentia, a paleogeographic term for the Canadian Shield and its surroundings, and Eurasia. It is the protocontinent of the Northern Hemisphere, corresponding to Gondwana in the Southern Hemisphere, from which the present continents of the Northern Hemisphere have been derived by separation and continental displacement. The hypothetical supercontinent from which both were derived is *Pangea*. The protocontinent included most of North America, Greenland, and most of Eurasia, excluding India. The main zone of separation was in the North Atlantic, with a branch in Hudson Bay; geologic features on opposite sides of these zones are very similar.

*Limestone* — A sedimentary rock consisting primarily of calcium carbonate (the mineral, calcite).

*Lithify* — To change to stone, or to petrify; esp. to consolidate from a loose sediment to a solid rock.

*Lithology* — The description of rocks on the basis of color, structures, mineral composition, and grain size; the physical character of a rock.

*Local relief* — The vertical difference in elevation between the highest and lowest points of a land surface within a specified horizontal distance or in a limited area.

*Loess* — A homogeneous, unstratified deposit of silt deposited by the wind.

*Member* — A rock-stratigraphic unit of subordinate rank, comprising some specially developed part of a varied formation (e.g., a subdivision of local extent only, or a unit with the same color, hardness, composition, and other rock properties that distinguish it from adjacent units in the formation). It may be formally defined and named, informally named, or unnamed; it is not necessarily mappable.

*Metamorphic rock* — Any rock derived from preexisting rocks by mineralogical, chemical, and structural changes, essentially in the solid state, in response to marked changes in temperature, pressure, shearing stress, and chemical environment at depth in the earth's crust (gneisses, schists, marbles, quartzites, etc.).

*Moraine* — A mound, ridge, or other distinct accumulation of...glacial drift, predominantly till, deposited...in a variety of topographic landforms that are independent of control by the surface on which the drift lies.

*Oolite* — A spherical to ellipsoidal body that has concentric or radial structure, or both, and that has grown in suspension in an agitating medium.

*Outwash* — Stratified drift (clay, silt, sand, gravel) deposited by meltwater streams in channels, deltas, and glacial lakes, and on outwash plains and floodplains.

*Outwash plain* — The surface of a broad body of outwash formed in front of a glacier.

*Overburden* — The upper part of a sedimentary deposit, compressing and consolidating the material below; or barren rock material overlying a mineral deposit.

*Pangea* — A hypothetical supercontinent supposed by many geologists to have existed very early in the geologic past, and to have combined all the continental crust from which the present continents were derived by fragmentation and movement away from each other by means of some form of continental displacement. During an intermediate stage of the fragmentation, between the existence of Pangea and that of the present, widely separated continents, Pangea was supposed to have split into two large fragments, *Laurasia* on the north and *Gondwana* on the south. The proto-ocean around Pangea has been termed *Panthalassa*. Other geologists, while accepting the former existence of Laurasia and Gondwana, are reluctant to concede the existence of an original Pangea; in fact, the early (Paleozoic or older) history of continental displacement remains largely undeciphered.

*Period* — An interval of geologic time; a division of an era.

*Permeability* — The property or capacity of a porous rock, sediment, or soil for transmitting a fluid without impairment of the structure of the medium.

*Physiography* — The study and classification of the surface features of Earth on the basis of similarities in geologic structure and the history of geologic changes.

*Physiographic province (or division)* — (a) A region, all parts of which are similar in geologic structure and climate and which has consequently had a unified geologic history; (b) a region whose pattern of relief features or landforms differs significantly from that of adjacent regions.

*Rank* — A coal classification based on degree of metamorphism.

**Relief** — (a) A term used loosely for the actual physical shape, configuration, or general unevenness of a part of the earth's surface, considered with reference to variations of height and slope or to irregularities of the land surface; the elevations or differences in elevation, considered collectively, of a land surface (frequently confused with topography). (b) The vertical difference in elevation between the hilltops or mountain summits and the lowlands or valleys of a given region: "high relief" has great variation; "low relief" has little variation.

**Sediment** — Solid fragmental material, either inorganic or organic, that originates from weathering of rocks and is transported by, suspended in, or deposited by air, water, or ice, or that is accumulated by other natural agents, such as chemical precipitation from solution or secretion from organisms, and that forms in layers on the earth's surface at ordinary temperatures in a loose, unconsolidated form; e.g. sand, gravel, silt, mud, till, loess, alluvium.

**Sedimentary rock** — A rock resulting from the consolidation of loose sediment that has accumulated in layers.

**Series** — A geologic time-stratigraphic unit; the strata deposited during an epoch; a division of a system.

**Stage, substage** — Geologic time-stratigraphic units; the strata formed during an age or subage, respectively.

**Stratigraphy** — the study, definition, and description of major and minor natural divisions of rocks, especially the study of the form, arrangement, geographic distribution, chronologic succession, classification, correlation, and mutual relationships of rock strata.

**Stratigraphic unit** — A stratum or body of strata recognized as a unit in the classification of the rocks of the earth's crust with respect to any specific rock character, property, or attribute or for any purpose such as description, mapping, and correlation.

**Stratum, plural strata** — A tabular or sheet-like mass, or a single and distinct layer, of homogeneous or gradational sedimentary material of any thickness, visually separable from other layers above and below by a discrete change in character of the material deposited or by a sharp physical break in deposition, or by both; a sedimentary *bed*.

**Stylolite** — A surface or contact, usually occurring in homogeneous carbonate rocks...that is marked by an irregular and interlocking penetration of the two sides; the columns, pits, and teeth-like projections on one side fit into their counterparts on the other. As usually seen in cross section, it resembles a suture or the tracing of a stylus. The seam is characterized by a concentration of insoluble constituents of the rock...and is commonly parallel to the bedding.

**System** — the largest, fundamental geologic time-stratigraphic unit; the strata of a system were deposited during a period of geologic time.

**Tectonic** — pertaining to the global forces involved in, or the resulting structures or features of the earth's movements.

**Till** — Unconsolidated, nonsorted, unstratified drift deposited by and underneath a glacier and consisting of a heterogeneous mixture of different sizes and kinds of rock fragments.

**Till plain** — The wavy surface of low relief in the area underlain by ground moraine.

**Topography** — The natural or physical surface features of a region, considered collectively as to form; the features revealed by the contour lines of a map.

**Unconformity** — A surface of erosion or nondeposition that separates younger strata from older strata; most unconformities indicate intervals of time when former areas of the sea bottom were temporarily raised above sea level.

**Valley trains** — The accumulations of outwash deposited by rivers in the valleys downstream from a glacier.





# PLEISTOCENE GLACIATIONS IN ILLINOIS

## Origin of the Glaciers

During the past million years or so, an interval of time called the Pleistocene Epoch, most of the northern hemisphere above the 50th parallel has been repeatedly covered by glacial ice. The cooling of the earth's surface, a prerequisite for glaciation, began at least 2 million years ago. On the basis of evidence found in subpolar oceans of the world (temperature-dependent fossils and oxygen-isotope ratios), a recent proposal has been made to recognize the beginning of the Pleistocene at 1.6 million years ago. Ice sheets formed in sub-arctic regions many times and spread outward until they covered the northern parts of Europe and North America. In North America, early studies of the glacial deposits led to the model that four glaciations could explain the observed distribution of glacial deposits. The deposits of a glaciation were separated from each other by the evidence of intervals of time during which soils formed on the land surface. In order of occurrence from the oldest to the youngest, they were given the names Nebraskan, Kansan, Illinoian, and Wisconsinan Stages of the Pleistocene Epoch. Work in the last 30 years has shown that there were more than four glaciations but the actual number and correlations at this time are not known. Estimates that are gaining credibility suggest that there may have been about 14 glaciations in the last one million years. In Illinois, estimates range from 4 to 8 based on buried soils and glacial deposits. For practical purposes, the previous four glacial stage model is functional, but we now know that the older stages are complex and probably contain more than one glaciation. Until we know more, all of the older glacial deposits, including the Nebraskan and Kansan will be classified as pre-Illinoian. The limits and times of the ice movement in Illinois are illustrated in the following pages by several figures.



The North American ice sheets developed when the mean annual temperature was perhaps 4° to 7°C (7° to 13°F) cooler than it is now and winter snows did not completely melt during the summers. Because the time of cooler conditions lasted tens of thousands of years, thick masses of snow and ice accumulated to form glaciers. As the ice thickened, the great weight of the ice and snow caused them to flow outward at their margins, often for hundreds of miles. As the ice sheets expanded, the areas in which snow accumulated probably also increased in extent.

Tongues of ice, called lobes, flowed southward from the Canadian centers near Hudson Bay and converged in the central lowland between the Appalachian and Rocky Mountains. There the glaciers made their farthest advances to the south. The sketch below shows several centers of flow, the general directions of flow from the centers, and the southern extent of glaciation. Because Illinois lies entirely in the central lowland, it has been invaded by glaciers from every center.

## Effects of Glaciation

Pleistocene glaciers and the waters melting from them changed the landscapes they covered. The glaciers scraped and smeared the landforms they overrode, leveling and filling many of the minor valleys and even some of the larger ones. Moving ice carried colossal amounts of rock and earth, for much of what the glaciers wore off the ground was kneaded into the moving ice and carried along, often for hundreds of miles.

The continual floods released by melting ice entrenched new drainageways, deepened old ones, and then partly refilled both with sediments as great quantities of rock and earth were carried beyond the glacier fronts. According to some estimates, the amount of water drawn from the sea and changed into ice during a glaciation was enough to lower the sea level from 300 to 400 feet below present level. Consequently, the melting of a continental ice sheet provided a tremendous volume of water that eroded and transported sediments.

In most of Illinois, then, glacial and meltwater deposits buried the old rock-ribbed, low, hill-and-valley terrain and created the flatter landforms of our prairies. The mantle of soil material and the buried deposits of gravel, sand, and clay left by the glaciers over about 90 percent of the state have been of incalculable value to Illinois residents.

## Glacial Deposits

The deposits of earth and rock materials moved by a glacier and deposited in the area once covered by the glacier are collectively called **drift**. Drift that is ice-laid is called **till**. Water-laid drift is called **outwash**.

Till is deposited when a glacier melts and the rock material it carries is dropped. Because this sediment is not moved much by water, a till is unsorted, containing particles of different sizes and compositions. It is also stratified (unlayered). A till may contain materials ranging in size from microscopic clay particles to large boulders. Most tills in Illinois are pebbly clays with only a few boulders. For descriptive purposes, a mixture of clay, silt, sand and boulders is called **diamicton**. This is a term used to describe a deposit that could be interpreted as till or a mass wasting product.

Tills may be deposited as **end moraines**, the arc-shaped ridges that pile up along the glacier edges where the flowing ice is melting as fast as it moves forward. Till also may be deposited as **ground moraines**, or **till plains**, which are gently undulating sheets deposited when the ice front melts back, or retreats. Deposits of till identify areas once covered by glaciers. Northeastern Illinois has many alternating ridges and plains, which are the succession of end moraines and till plains deposited by the Wisconsinan glacier.

Sorted and stratified sediment deposited by water melting from the glacier is called **outwash**. Outwash is bedded, or layered, because the flow of water that deposited it varied in gradient, volume, velocity, and direction. As a meltwater stream washes the rock materials along, it sorts them by size—the fine sands, silts, and clays are carried farther downstream than the coarser gravels and cobbles. Typical Pleistocene outwash in Illinois is in multilayered beds of clays, silts, sands, and gravels that look much like modern stream deposits in some places. In general, outwash tends to be coarser and less weathered, and alluvium is most often finer than medium sand and contains variable amounts of weathered material.

Outwash deposits are found not only in the area covered by the ice field but sometimes far beyond it. Meltwater streams ran off the top of the glacier, in crevices in the ice, and under the ice. In some places, the cobble-gravel-sand filling of the bed of a stream that flowed in the ice is preserved as a sinuous ridge called an **esker**. Some eskers in Illinois are made up of sandy to silty deposits and contain mass wasted diamicton material. Cone-shaped mounds of coarse outwash, called **kames**, were formed where meltwater plunged through crevasses in the ice or into ponds on the glacier.

The finest outwash sediments, the clays and silts, formed bedded deposits in the ponds and lakes that filled glacier-dammed stream valleys, the sags of the till plains, and some low, moraine-diked till plains. Meltwater streams that entered a lake rapidly lost speed and also quickly dropped the sands and gravels they carried, forming deltas at the edge of the lake. Very fine sand and silts were commonly redistributed on the lake bottom by wind-generated currents, and the clays, which stayed in suspension longest, slowly settled out and accumulated with them.

Along the ice front, meltwater ran off in innumerable shifting and short-lived streams that laid down a broad, flat blanket of outwash that formed an **outwash plain**. Outwash was also carried away from the glacier in valleys cut by floods of meltwater. The Mississippi, Illinois, and Ohio Rivers occupy valleys that were major channels for meltwaters and were greatly widened and deepened during times of the greatest meltwater floods. When the floods waned, these valleys were partly filled with outwash far beyond the ice margins. Such outwash deposits, largely sand and gravel, are known as **valley trains**. Valley train deposits may be both extensive and thick. For instance, the long valley train of the Mississippi Valley is locally as much as 200 feet thick.



## Loess, Eolian Sand and Soils

One of the most widespread sediments resulting from glaciation was carried not by ice or water but by wind. **Loess** is the name given to windblown deposits dominated by silt. Most of the silt was derived from wind erosion of the valley trains. Wind action also sorted out **eolian sand** which commonly formed **sand dunes** on the valley trains or on the adjacent uplands. In places, sand dunes have migrated up to 10 miles away from the principle source of sand. Flat areas between dunes are generally underlain by eolian **sheet sand** that is commonly reworked by water action. On uplands along the major valley trains, loess and eolian sand are commonly interbedded. With increasing distance from the valleys, the eolian sand pinches out, often within one mile.

Eolian deposition occurred when certain climatic conditions were met, probably in a seasonal pattern. Deposition could have occurred in the fall, winter or spring season when low precipitation rates and low temperatures caused meltwater floods to abate, exposing the surfaces of the valley trains and permitting them to dry out. During Pleistocene time, as now, west winds prevailed, and the loess deposits are thickest on the east sides of the source valleys. The loess thins rapidly away from the valleys but extends over almost all the state.

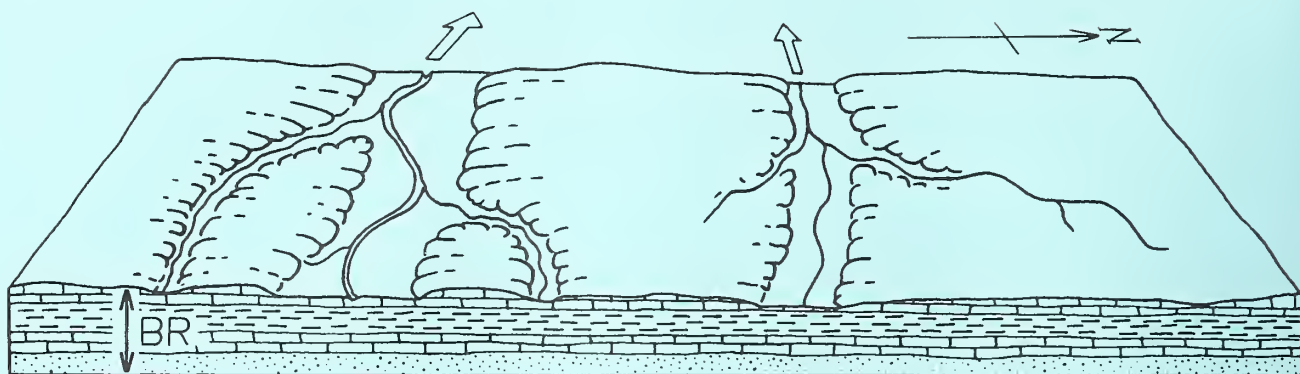
Each Pleistocene glaciation was followed by an interglacial stage that began when the climate warmed enough to melt the glaciers and their snowfields. During these warmer intervals, when the climate was similar to that of today, drift and loess surfaces were exposed to weather and the activities of living things. Consequently, over most of the glaciated terrain, soils developed on the Pleistocene deposits and altered their composition, color, and texture. Such soils were generally destroyed by later glacial advances, but some were buried. Those that survive serve as "key beds," or stratigraphic markers, and are evidence of the passage of a long interval of time.

## Glaciation in a Small Illinois Region

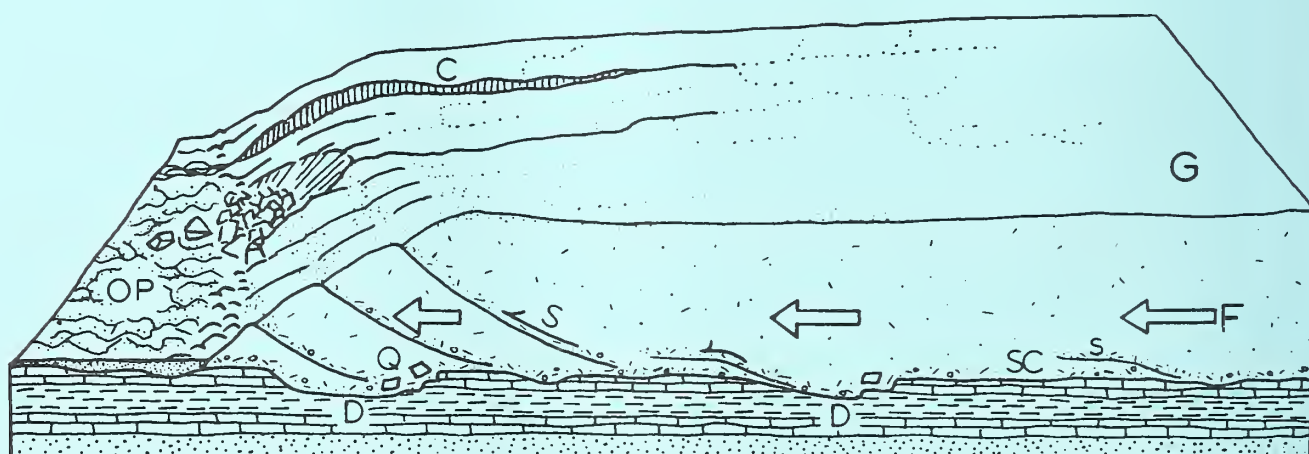
The following diagrams show how a continental ice sheet might have looked at various stages as it moved across a small region in Illinois. They illustrate how it could change the old terrain and create a landscape like the one we live on. To visualize how these glaciers looked, geologists study the landforms and materials left in the glaciated regions and also the present-day mountain glaciers and polar ice caps.

The block of land in the diagrams is several miles wide and about 10 miles long. The vertical scale is exaggerated—layers of material are drawn thicker and landforms higher than they ought to be so that they can be easily seen.





1. **The Region Before Glaciation** — Like most of Illinois, the region illustrated is underlain by almost flat-lying beds of sedimentary rocks—layers of sandstone (.....), limestone (— — —), and shale (|||). Millions of years of erosion have planed down the bedrock (BR), creating a terrain of low uplands and shallow valleys. A residual soil weathered from local rock debris covers the area but is too thin to be shown in the drawing. The streams illustrated here flow westward and the one on the right flows into the other at a point beyond the diagram.



2. **The Glacier Advances Southward** — As the Glacier (G) spreads out from its ice snowfield accumulation center, it scours (SC) the soil and rock surface and quarries (Q)—pushes and plucks up—chunks of bedrock. The materials are mixed into the ice and make up the glacier's "load." Where roughnesses in the terrain slow or stop flow (F), the ice "current" slides up over the blocked ice on innumerable shear planes (S). Shearing mixes the load very thoroughly. As the glacier spreads, long cracks called "crevasses" (C) open parallel to the direction of ice flow. The glacier melts as it flows forward, and its meltwater erodes the terrain in front of the ice, deepening (D) some old valleys before ice covers them. Meltwater washes away some of the load freed by melting and deposits it on the outwash plain (OP). The advancing glacier overrides its outwash and in places scours much of it up again. The glacier may be 5000 or so feet thick, and tapers to the margin, which was probably in the range of several hundred feet above the old terrain. The ice front advances perhaps as much as a third of a mile per year.



# TIME TABLE OF PLEISTOCENE GLACIATION

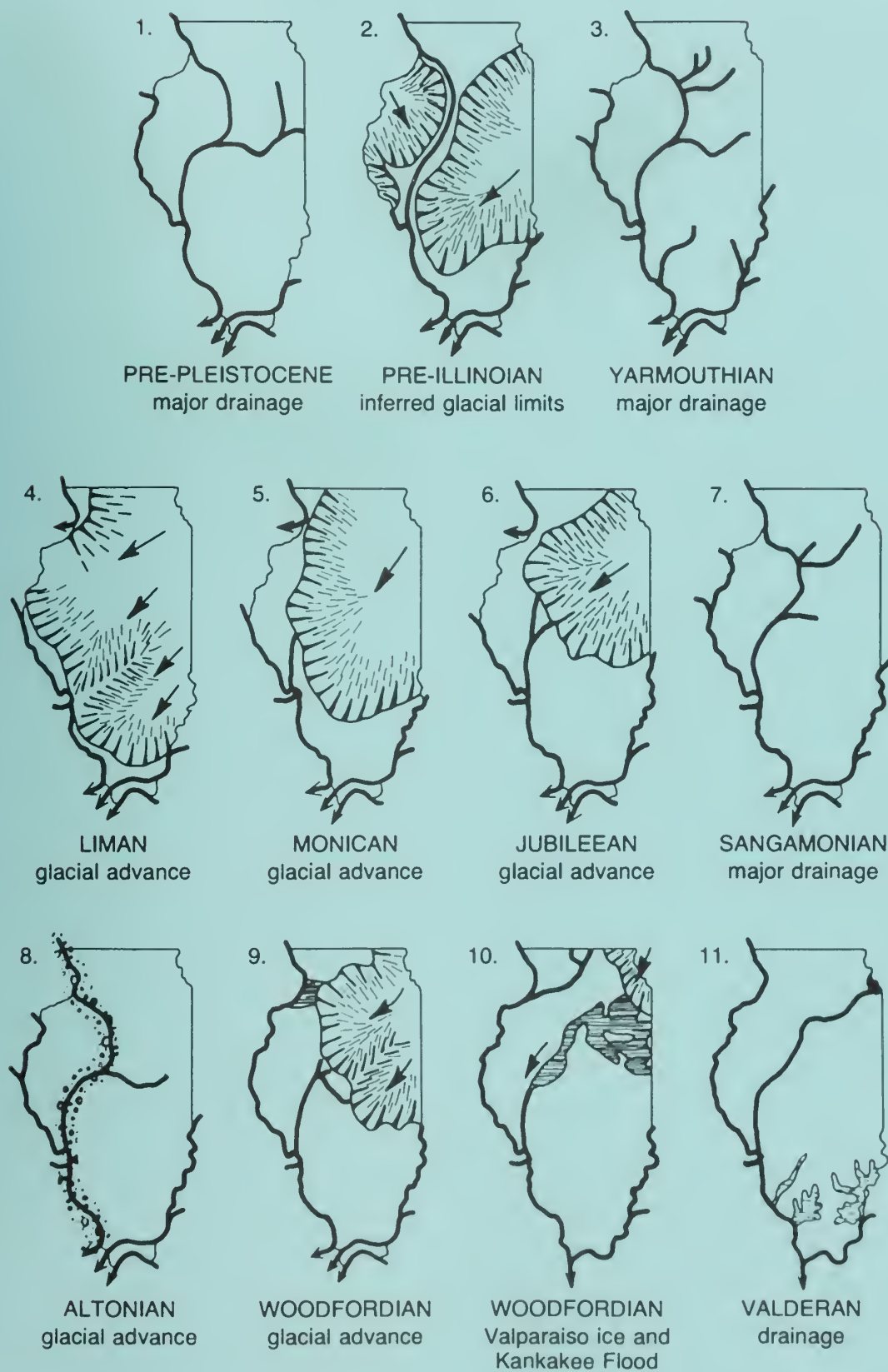
|            |               | STAGE                         | SUBSTAGE                | NATURE OF DEPOSITS                                                                  | SPECIAL FEATURES                                                                                                                  |
|------------|---------------|-------------------------------|-------------------------|-------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|
| QUATERNARY | Pleistocene   | HOLOCENE<br>(interglacial)    | Years<br>Before Present | Soil, youthful profile<br>of weathering, lake<br>and river deposits,<br>dunes, peat |                                                                                                                                   |
|            |               | WISCONSINAN<br>(glacial)      | 10,000                  |                                                                                     |                                                                                                                                   |
|            |               |                               | Valderan                | Outwash, lake deposits                                                              | Outwash along<br>Mississippi Valley                                                                                               |
|            |               |                               | 11,000                  |                                                                                     |                                                                                                                                   |
|            |               |                               | Twocreekan              | Peat and alluvium                                                                   | Ice withdrawal, erosion                                                                                                           |
|            |               |                               | 12,500                  |                                                                                     |                                                                                                                                   |
|            |               |                               | Woodfordian             | Drift, loess, dunes,<br>lake deposits                                               | Glaciation; building of<br>many moraines as far<br>south as Shelbyville;<br>extensive valley trains,<br>outwash plains, and lakes |
|            |               |                               | 25,000                  |                                                                                     |                                                                                                                                   |
|            |               |                               | Farmdalian              | Soil, silt, and peat                                                                | Ice withdrawal, weathering,<br>and erosion                                                                                        |
|            |               |                               | 28,000                  |                                                                                     |                                                                                                                                   |
|            |               |                               | Altonian                | Drift, loess                                                                        | Glaciation in Great Lakes<br>area, valley trains<br>along major rivers                                                            |
|            |               | SANGAMONIAN<br>(interglacial) | 75,000                  | Soil, mature profile<br>of weathering                                               | Important stratigraphic marker                                                                                                    |
|            |               |                               | 125,000                 |                                                                                     |                                                                                                                                   |
|            |               | ILLINOIAN<br>(glacial)        | Jubileean               | Drift, loess, outwash                                                               | Glaciers from northeast<br>at maximum reached<br>Mississippi River and<br>nearly to southern tip<br>of Illinois                   |
|            |               |                               | Monican                 | Drift, loess, outwash                                                               |                                                                                                                                   |
|            |               |                               | Liman                   | Drift, loess, outwash                                                               |                                                                                                                                   |
|            |               | YARMOUTHIAN<br>(interglacial) | 300,000?                | Soil, mature profile<br>of weathering                                               | Important stratigraphic marker                                                                                                    |
|            |               |                               | 500,000?                |                                                                                     |                                                                                                                                   |
|            | Pre-Illinoian | KANSAN*<br>(glacial)          |                         | Drift, loess                                                                        | Glaciers from northeast<br>and northwest covered<br>much of state                                                                 |
|            |               | AFTONIAN*<br>(interglacial)   | 700,000?                | Soil, mature profile<br>of weathering                                               | (hypothetical)                                                                                                                    |
|            |               | NEBRASKAN*<br>(glacial)       | 900,000?                | Drift (little known)                                                                | Glaciers from northwest<br>invaded western Illinois                                                                               |
|            |               |                               | 1,600,000 or more       |                                                                                     |                                                                                                                                   |

\*Old oversimplified concepts, now known to represent a series of glacial cycles.

(Illinois State Geological Survey, 1973)



# SEQUENCE OF GLACIATIONS AND INTERGLACIAL DRAINAGE IN ILLINOIS



(Modified from Willman and Frye, "Pleistocene Stratigraphy of Illinois," ISGS Bull. 94, fig. 5, 1970.)

# WOODFORDIAN MORAINES

H. B. Willman and John C. Frye

1970

Boundary of  
Woodfordian glaciation

Temperance Hill

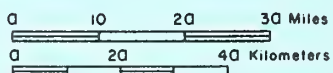
BLOOMINGTON

MARSEILLES

MARSEILLES

WOODFORDIAN

- Le Roy Named moraine
- ILLIANA Named morainic system
- Intermorainal area





# GLACIAL MAP OF ILLINOIS


H.B. WILLMAN and JOHN C. FRYE

1970

Modified from maps by Leverett (1899),  
Exblow (1959), Leighton and Brophy (1961),  
Willman et al. (1967), and others

## EXPLANATION

### HOLOCENE AND WISCONSINAN

 Alluvium, sand dunes,  
and gravel terraces


### WISCONSINAN

 Lake deposits

### WOODFORDIAN

 Moraine

 Front of morainic system

 Ground moraine

### ALTONIAN

 Till plain

### ILLINOIAN

 Moraine and ridged drift

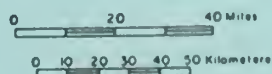
 Ground moraine

### KANSAN

 Till plain

### DRIFTLESS





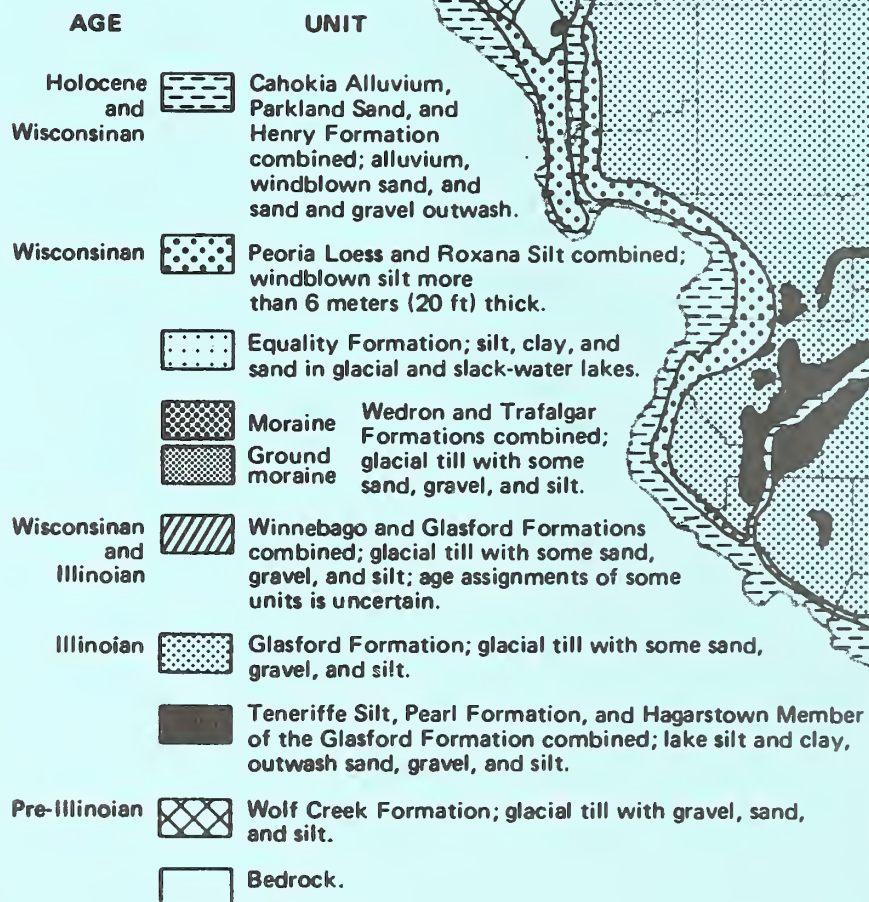


# QUATERNARY DEPOSITS OF ILLINOIS

Jerry A. Lineback

1981

Modified from Quaternary Deposits  
of Illinois (1979) by Jerry A. Lineback





ERRATICS ARE ERRATIC

*Myrna M. Killey*

You may have seen them scattered here and there in Illinois—boulders, some large, some small, lying alone or with a few companions in the corner of a field, at the edge of a road, in someone's yard, or perhaps on a courthouse lawn or schoolyard. Many of them seem out of place, like rough, alien monuments in the stoneless, grassy knolls and prairies of our state. Some—the colorful and glittering granites, banded gneisses, and other intricately veined and streaked igneous and metamorphic rocks—are indeed foreign rocks, for they came from Canada and the states north of us. Others—gray and tan sedimentary rocks—are native rocks and may be no more than a few miles from their place of origin. All of these rocks are glacial boulders that were moved to their present sites by massive ice sheets that flowed across our state. If these boulders are unlike the rocks in the quarries and outcrops in the region where they are found, they are called erratics.

The continental glaciers of the Great Ice Age scoured and scraped the land surface as they advanced, pushing up chunks of bedrock and grinding them against each other or along the ground surface as the rock-laden ice sheets pushed southward. Hundreds of miles of such grinding, even on such hard rocks as granite, eventually rounded off the sharp edges of these passengers in the ice until they became the rounded, irregular boulders we see today. Although we do not know the precise manner in which erratics reached their present isolated sites, many were

probably dropped directly from the melting front of a glacier. Others may have been rafted to their present resting places by icebergs on ancient lakes or on the floodwaters of some long-vanished stream as it poured from a glacier. Still others, buried in the glacial deposits, could have worked their way up to the land surface as the surrounding loose soil repeatedly froze and thawed. When the freezing ground expands, pieces of rock tend to be pushed upward, where they are more easily reached by the farmer's plow and also more likely to be exposed by erosion.



An eight-foot boulder of pink granite left by a glacier in the bed of a creek about 5 miles southwest of Alexis, Warren County, Illinois. (From ISGS Bulletin 57, 1929.)

Generally speaking, erratics found northeast of a line drawn from Freeport in Stephenson County, southward through Peoria, and then southeastward through Shelbyville to Marshall at the east edge of the state were brought in by the last glacier to enter Illinois. This glaciation, called the Wisconsinan, spread southwestward into Illinois from a center in eastern Canada, reaching our state about 75,000 years ago and (after repeated advances and retreats of the ice margin) melting from the state about 12,500 years ago. Erratics to the west or south of the great arc outlined above were brought in by a much older glacier, the Illinoian, which spread over most of the state about 300,000 to 175,000 years ago. Some erratics were brought in by even older glaciers that came from the northwest.

You may be able to locate some erratics in your neighborhood. Sometimes it is possible to tell where the rock originally came from by determining the kind of rock it is. A large boulder of granite, gneiss, or other igneous or metamorphic rock may have come from the Canadian Shield, a vast area in central and eastern Canada where rocks of Precambrian age (more than 600 million years old) are exposed at the surface. Some erratics containing flecks of copper were probably transported here from the "Copper Range" of the upper peninsula of Michigan. Large pieces of copper have been found in glacial deposits of central and northern Illinois. Light gray to white quartzite boulders with beautiful, rounded pebbles of red jasper came from a very small outcrop area near Bruce Mines, Ontario, Canada. Purplish pieces of quartzite, some of them banded, probably originated in the Baraboo Range of central Wisconsin. Most interesting of all are the few large boulders of Canadian tillite. Tillite is lithified (hardened into rock) glacial till deposited by a Precambrian glacier many millions of years older than the ones that invaded our state a mere few thousand years ago. Glacial till is an unsorted and unlayered mixture of clay, sand, gravel, and boulders that vary widely in size and shape. Tillite is a gray to greenish gray rock containing a mixture of grains of different sizes and scattered pebbles of various types and sizes.

Many erratics are of notable size and beauty, and in parts of Illinois they are commonly used in landscaping. Some are used as monuments in courthouse squares, in parks, or along highways. Many are marked with metal plaques to indicate an interesting historical spot or event. Keep an eye out for erratics. There may be some of these glacial strangers in your neighborhood that would be interesting to know.



ANCIENT DUST STORMS IN ILLINOIS

*Myrna M. Killey*

Fierce dust storms whirled across Illinois long before human beings were here to record them. Where did all the dust come from? Geologists have carefully put together clues from the earth itself to get the story. As the glaciers of the Great Ice Age scraped and scoured their way southward across the landscape from Canada, they moved colossal amounts of rock and earth. Much of the rock ground from the surface was kneaded into the ice and carried along, often for hundreds of miles. The glaciers acted as giant grist mills, grinding much of the rock and earth to "flour"—very fine dust-sized particles.

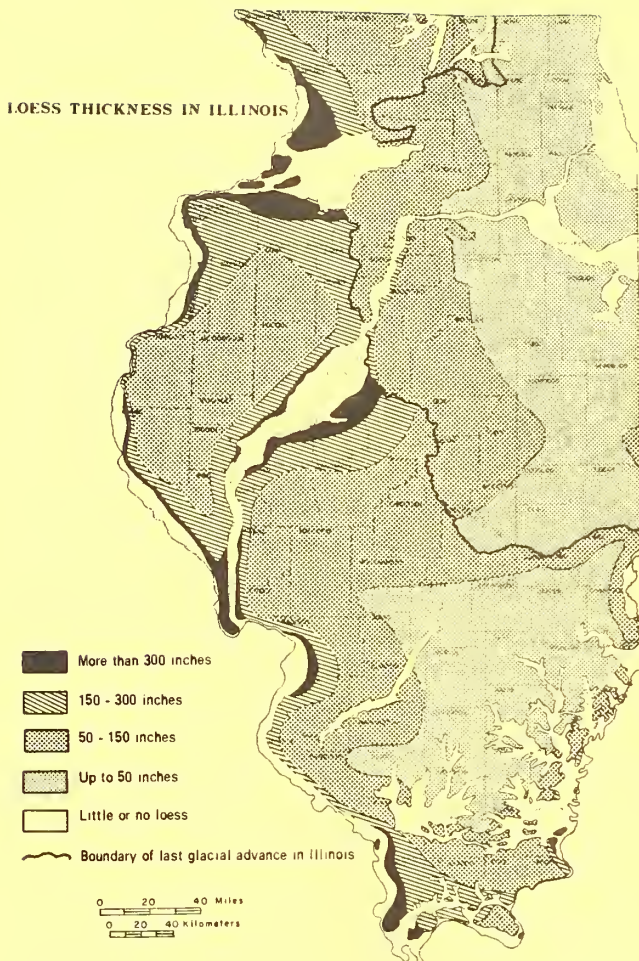
During the warm seasons, water from the melting ice poured from the glacier front, laden with this rock flour, called silt. In the cold months the melt-water stopped flowing and the silt was left along the channels the water had followed, where it dried out and became dust. Strong winds picked up the dust, swept it from the floodplains, and carried it to adjacent uplands. There the forests along the river valleys trapped the dust, which became part of the moist forest soil. With each storm more material accumulated until the high bluffs adjacent to major rivers were formed. The dust deposits are thicker along the eastern sides of the valleys than they are on the western sides, a fact from which geologists deduce that the prevailing winds of that time blew from west to east, the same direction as those of today. From such clues geologists conclude that the geologic processes of the past were much like those of today.

The deposits of windblown silt are called loess (rhymes with "bus"). Loess is found not only in the areas once covered by the glaciers but has been blown into the nonglaciated areas. The glaciers, therefore, influenced the present land surface well beyond the line of their farthest advance.

Loess has several interesting characteristics. Its texture is so fine and uniform that it can easily be identified in roadcuts—and because it blankets such a vast area many roads are cut through it. Even more noticeable is its tendency to stand in vertical walls. These steep walls develop as the loess drains and becomes tough, compact, and massive, much like a rock. Sometimes cracks develop in the loess, just as they do in massive limestones and sandstones. Loess makes good highway banks if it is cut vertically. A vertical cut permits maximum drainage because little surface is exposed to rain, and rainwater tends to drain straight down through it to the rock underneath. If the bank is cut at an angle more water soaks in, which causes the loess to slump down. Along Illinois roads the difference between a loess roadcut and one in ordinary glacial till is obvious. The loess has a very uniform texture, while the till is composed of a random mixture of rock debris, from clay and silt through cobbles and boulders.

Many loess deposits are worth a close look. Through a 10-power hand lens separate grains can be seen, among them many clear, glassy, quartz grains. Some loess deposits contain numerous rounded, lumpy stones called concretions. Their formation began when water percolating through the loess dissolved tiny

LOESS THICKNESS IN ILLINOIS



limestone grains. Some of the dissolved minerals later became solid again, gathering around a tiny nucleus or along roots to form the lumpy masses. A few such concretions are shaped roughly like small dolls and, from this resemblance, are called "loess kindchen," a German term meaning "loess children." They may be partly hollow and contain smaller lumps that make them rattle when shaken.

Fossil snails can be found in some loess deposits. The snails lived on the river bluffs while the loess was being deposited and were buried by the dust. When they are abundant, they are used to determine how old the loess is. The age is found by measuring the amount of radioactive carbon in the calcium carbonate of their shells.

Some of the early loess deposits were covered by new layers of loess following later glacial invasions. Many thousands of years passed between the major glacial periods, during which time the climate was as warm as that of today. During the warm intervals, the surface of the loess and other glacial deposits was exposed to weather. Soils developed on most of the terrain, altering the composition, color, and texture of the glacial material.

During later advances of the ice, some of these soils were destroyed, but in many places they are preserved under the younger sediments. Such ancient buried soils can be used to determine when the materials above and below them were laid down by the ice and what changes in climate took place.

The blanket of loess deposited by the ancient dust storms forms the parent material of the rich, deep soils that today are basic to the state's agriculture. A soil made of loess crumbles easily and has great moisture-holding capacity. It also is free from rocks that might complicate cultivation. Those great dust storms that swirled over the land many thousands of years ago thus endowed Illinois with one of its greatest resources, its highly productive soil.



## DEPOSITIONAL HISTORY OF THE PENNSYLVANIAN ROCKS IN ILLINOIS

At the close of the Mississippian Period, about 310 million years ago, the sea withdrew from the Midcontinent region. A long interval of erosion that took place early in Pennsylvanian time removed hundreds of feet of the pre-Pennsylvanian strata, completely stripping them away and cutting into older rocks over large areas of the Midwest. Ancient river systems cut deep channels into the bedrock surface. Later, but still during early Pennsylvanian (Morrowan) time, the sea level started to rise; the corresponding rise in the base level of deposition interrupted the erosion and led to filling the valleys in the erosion surface with fluvial, brackish, and marine sands and muds.

Depositional conditions in the Illinois Basin during the Pennsylvanian Period were somewhat similar to those of the preceding Chesterian (late Mississippian) time. A river system flowed southwestward across a swampy lowland, carrying mud and sand from highlands to the northeast. This river system formed thin but widespread deltas that coalesced into a vast coastal plain or lowland that prograded (built out) into the shallow sea that covered much of present-day Illinois (see paleogeographic map, next page). As the lowland stood only a few feet above sea level, slight changes in relative sea level caused great shifts in the position of the shoreline.

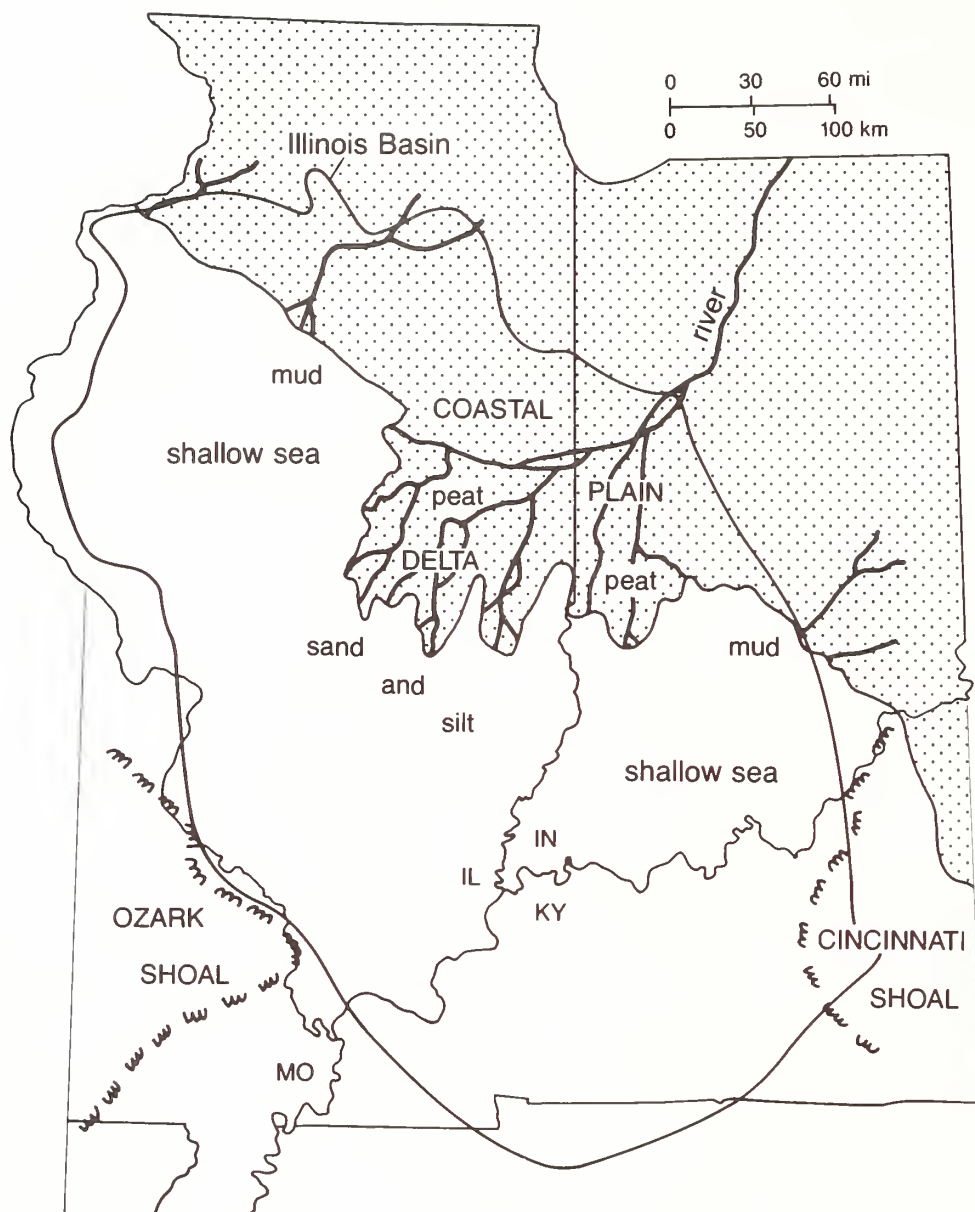
During most of Pennsylvanian time, the Illinois Basin gradually subsided; a maximum of about 3000 feet of Pennsylvanian sediments are preserved in the basin. The locations of the delta systems and the shoreline of the resulting coastal plain shifted, probably because of worldwide sea level changes, coupled with variation in the amounts of sediments provided by the river system and local changes in basin subsidence rates. These frequent shifts in the coastline position caused the depositional conditions at any one locality in the basin to alternate frequently between marine and nonmarine, producing a variety of lithologies in the Pennsylvanian rocks (see lithology distribution chart).

Conditions at various places on the shallow sea floor favored the deposition of sand, lime mud, or mud. Sand was deposited near the mouths of distributary channels, where it was reworked by waves and spread out as thin sheets near the shore. Mud was deposited in quiet-water areas — in delta bays between distributaries, in lagoons behind barrier bars, and in deeper water beyond the nearshore zone of sand deposition. Limestone was formed from the accumulation of limy parts of plants and animals laid down in areas where only minor amounts of sand and mud were being deposited. The areas of sand, mud, and limy mud deposition continually changed as the position of the shoreline changed and as the delta distributaries extended seaward or shifted their positions laterally along the shore.

Nonmarine sand, mud, and lime mud were deposited on the coastal plain bordering the sea. The nonmarine sand was deposited in delta distributary channels, in river channels, and on the broad floodplains of the rivers. Some sand bodies 100 or more feet thick were deposited in channels that cut through the underlying rock units. Mud was deposited mainly on floodplains. Some mud and freshwater lime mud were deposited locally in fresh-water lakes and swamps.

Beneath the quiet water of extensive swamps that prevailed for long intervals on the emergent coastal lowland, peat was formed by accumulation of plant material. Lush forest vegetation covered the region; it thrived in the warm, moist Pennsylvanian-age climate. Although the origin of the underclays beneath the coal is not precisely known, most evidence indicates that they were deposited in the swamps as slackwater mud before the accumulation of much plant debris. The clay underwent modification to become the soil upon which the lush vegetation grew in the swamps. Underclay frequently contains plant roots and rootlets that appear to be in their original places. The vast swamps were the culmination of nonmarine deposition. Resubmergence of the borderlands by the sea interrupted nonmarine deposition, and marine sediments were laid down over the peat.



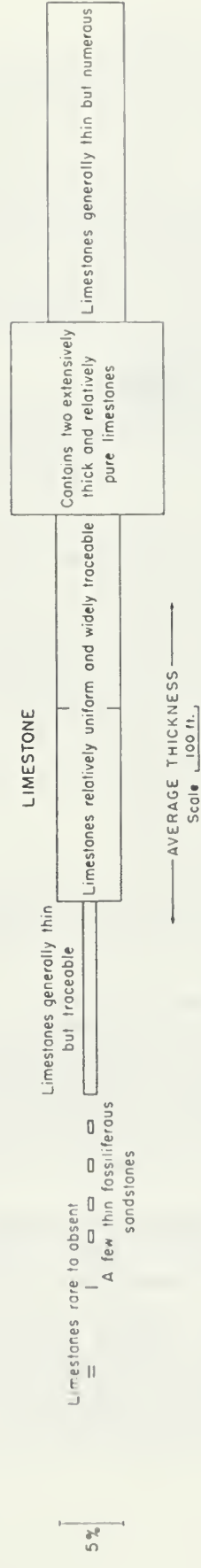
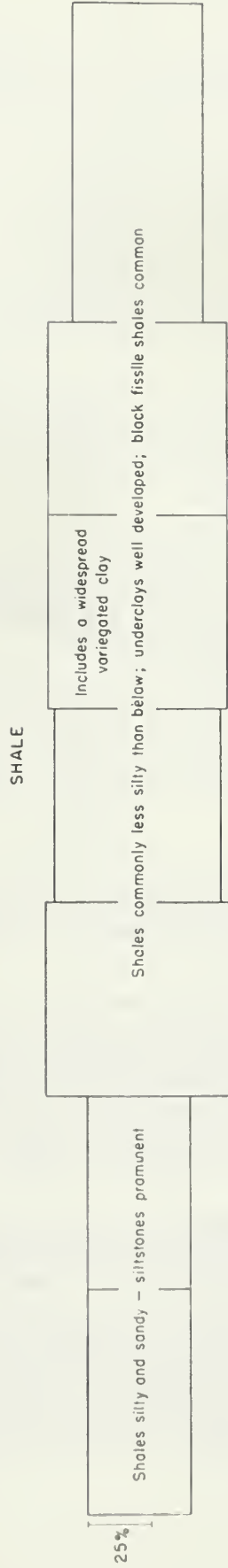


Paleogeography of Illinois-Indiana region during Pennsylvanian time. The diagram shows a Pennsylvanian river delta and the position of the shoreline and the sea at an instant of time during the Pennsylvanian Period.

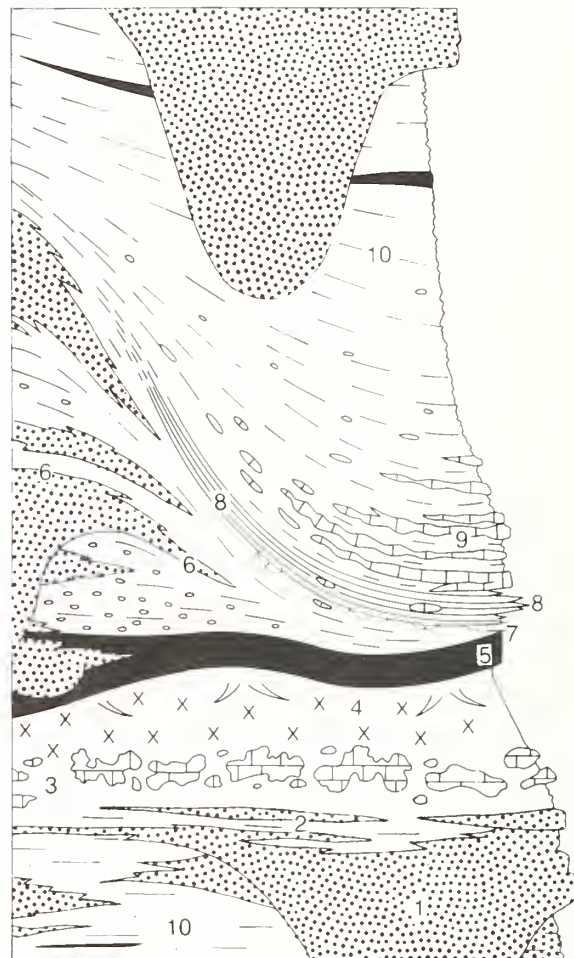
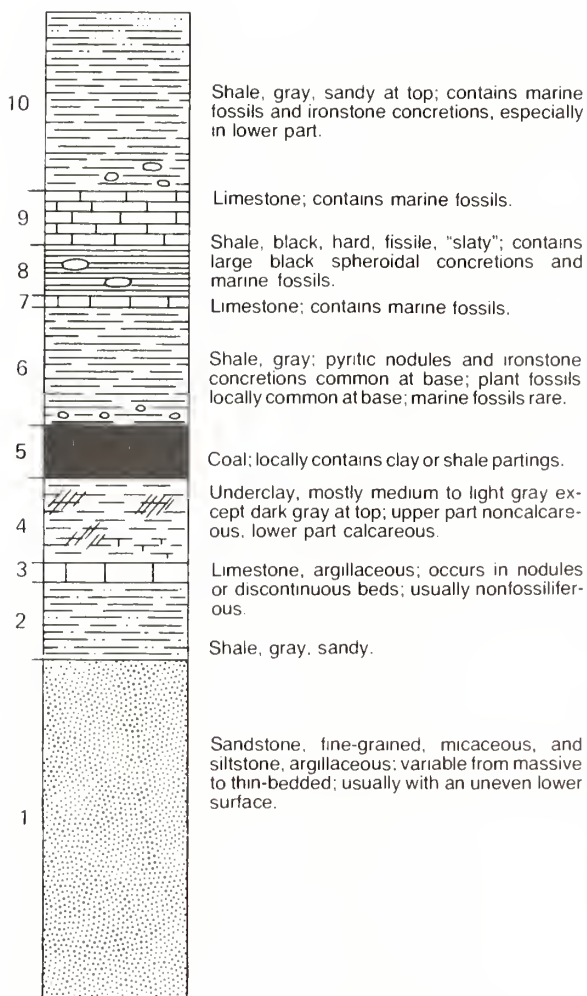
### Pennsylvanian Cyclothems

The Pennsylvanian strata exhibit extraordinary variations in thickness and composition both laterally and vertically because of the extremely varied environmental conditions under which they formed. Individual sedimentary units are often only a few inches thick and rarely exceed 30 feet thick. Sandstones and shales commonly grade laterally into each other, and shales sometimes interfinger and grade into limestones and coals. The underclays, coals, black shales, and some limestones, however, display remarkable lateral continuity for such thin units. Coal seams have been traced in mines, outcrops, and subsurface drill records over areas comprising several states.

| McCORMICK GROUP |            | KEWANEE GROUP |                | MCLEANSBORO GROUP |             |
|-----------------|------------|---------------|----------------|-------------------|-------------|
| Caseyville Fm.  | Abbott Fm. | Spoon Fm.     | Carbondale Fm. | Modesto Fm.       | Bond Fm.    |
|                 |            |               |                |                   | Mattoon Fm. |



General distribution of the four principal lithologies in Pennsylvanian strata of Illinois.



The idealized cyclothem at left (after Willman and Payne, 1942) infers continuous, widespread distribution of individual cyclothem units, at right the model of a typical cyclothem (after Baird and Shabica, 1980) shows the discontinuous nature of many units in a cyclothem.

The rapid and frequent changes in depositional environments during Pennsylvanian time produced regular or cyclical alternations of sandstone, shale, limestone, and coal in response to the shifting shoreline. Each series of alternations, called a cyclothem, consists of several marine and nonmarine rock units that record a complete cycle of marine invasion and retreat. Geologists have determined, after extensive studies of the Pennsylvanian strata in the Midwest, that an "ideally" complete cyclothem consists of ten sedimentary units (see illustration above contrasting the model of an "ideal" cyclothem with a model showing the dynamic relationships between the various members of a typical cyclothem).

Approximately 50 cyclothems have been described in the Illinois Basin but only a few contain all ten units at any given location. Usually one or more are missing because conditions of deposition were more varied than indicated by the "ideal" cyclothem. However, the order of units in each cyclothem is almost always the same: a typical cyclothem includes a basal sandstone overlain by an underclay, coal, black sheeted shale, marine limestone, and gray marine shale. In general, the sandstone-underclay-coal-gray shale portion (the lower six units) of each cyclothem is nonmarine: it was deposited as part of the coastal lowlands from which the sea had withdrawn. However, some of the sandstones are entirely or partly marine. The units above the coal and gray shale are marine sediments deposited when the sea advanced over the coastal plain.



## Origin of Coal

It is generally accepted that the Pennsylvanian coals originated by the accumulation of vegetable matter, usually in place, beneath the waters of extensive, shallow, fresh-to-brackish swamps. They represent the last-formed deposits of the nonmarine portions of the cyclothem. The swamps occupied vast areas of the coastal lowland, which bordered the shallow Pennsylvanian sea. A luxuriant growth of forest plants, many quite different from the plants of today, flourished in the warm, humid Pennsylvanian climate. (Illinois at that time was near the equator.) The deciduous trees and flowering plants that are common today had not yet evolved. Instead, the jungle-like forests were dominated by giant ancestors of present-day club mosses, horsetails, ferns, conifers, and cycads. The undergrowth also was well developed, consisting of many ferns, fernlike plants, and small club mosses. Most of the plant fossils found in the coals and associated sedimentary rocks show no annual growth rings, suggesting rapid growth rates and lack of seasonal variations in the climate (tropical). Many of the Pennsylvanian plants, such as the seed ferns, eventually became extinct.

Plant debris from the rapidly growing swamp forests — leaves, twigs, branches, and logs — accumulated as thick mats of peat on the floors of the swamps. Normally, vegetable matter rapidly decays by oxidation, forming water, nitrogen, and carbon dioxide. However, the cover of swamp water, which was probably stagnant and low in oxygen, prevented oxidation, and any decay of the peat deposits was due primarily to bacterial action.

The periodic invasions of the Pennsylvanian sea across the coastal swamps killed the Pennsylvanian forests, and the peat deposits were often buried by marine sediments. After the marine transgressions, peat usually became saturated with sea water containing sulfates and other dissolved minerals. Even the marine sediments being deposited on the top of the drowned peat contained various minerals in solution, including sulfur, which further infiltrated the peat. As a result, the peat developed into a coal that is high in sulfur. However, in a number of areas, nonmarine muds, silts, and sands from the river system on the coastal plain covered the peat where flooding broke through levees or the river changed its course. Where these sediments (unit 6 of the cyclothem) are more than 20 feet thick, we find that the coal is low in sulfur, whereas coal found directly beneath marine rocks is high in sulfur. Although the seas did cover the areas where these nonmarine, fluvial sediments covered the peat, the peat was protected from sulfur infiltration by the shielding effect of these thick fluvial sediments.

Following burial, the peat deposits were gradually transformed into coal by slow physical and chemical changes in which pressure (compaction by the enormous weight of overlying sedimentary layers), heat (also due to deep burial), and time were the most important factors. Water and volatile substances (nitrogen, hydrogen, and oxygen) were slowly driven off during the coal-forming ("coalification") process, and the peat deposits were changed into coal.

Coals have been classified by ranks that are based on the degree of coalification. The commonly recognized coals, in order of increasing rank, are (1) brown coal or lignite, (2) sub-bituminous, (3) bituminous, (4) semibituminous, (5) semianthracite, and (6) anthracite. Each increase in rank is characterized by larger amounts of fixed carbon and smaller amounts of oxygen and other volatiles. Hardness of coal also increases with increasing rank. All Illinois coals are classified as bituminous.

Underclays occur beneath most of the coals in Illinois. Because underclays are generally unstratified (unlayered), are leached to a bleached appearance, and generally contain plant roots, many geologists consider that they represent the ancient soils on which the coal-forming plants grew.

The exact origin of the carbonaceous black shale that occurs above many coals is uncertain. Current thinking suggests that the black shale actually represents the deepest part of the marine transgression. Maximum transgression of the sea, coupled with upwelling of ocean water and accumulation of mud and animal remains on an anaerobic ocean floor, led to the deposition of black organic mud over vast areas stretching from Texas to Illinois. Deposition occurred in quiet-water areas where the very fine-grained iron-rich



mud and finely divided plant debris were washed in from the land. Most of the fossils found in black shale represent planktonic (floating) and nektonic (swimming) forms — not benthonic (bottom-dwelling) forms. The depauperate (dwarf) fossil forms sometimes found in black shale formerly were thought to have been forms that were stunted by toxic conditions in the sulfide-rich, oxygen-deficient water of the lagoons. However, study has shown that the “depauperate” fauna consists mostly of normal-size individuals of species that never grew any larger.

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- Willman, H. B., E. Atherton, T. C. Buschbach, C. W. Collinson, J. C. Frye, M. E. Hopkins, J. A. Lineback, and J. A. Simon, 1975, Handbook of Illinois Stratigraphy: Illinois State Geological Survey Bulletin 95, 261 p.





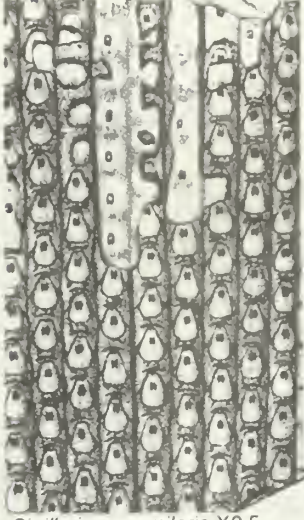
# Common Pennsylvanian plants: lycopods, sphenophytes, and ferns



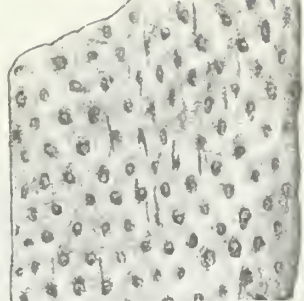
*Lepidodendron aculeatum* X0.8



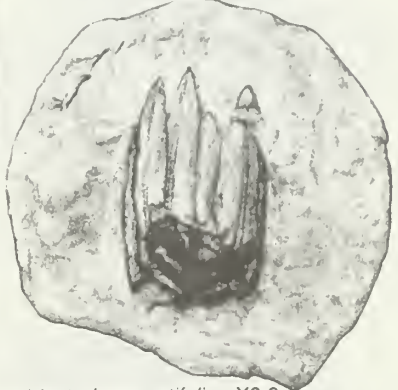
*Lepidophloios laricinus* X0.63



*Sigillaria mammilaris* X0.5



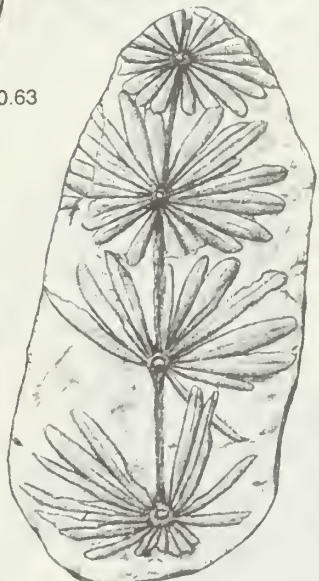
*Stigmara ficoides* X0.32



*Lepidostrobus ovatifolius* X0.8



*Calamites suckowii* X0.5



*Annularia stellata* X0.63



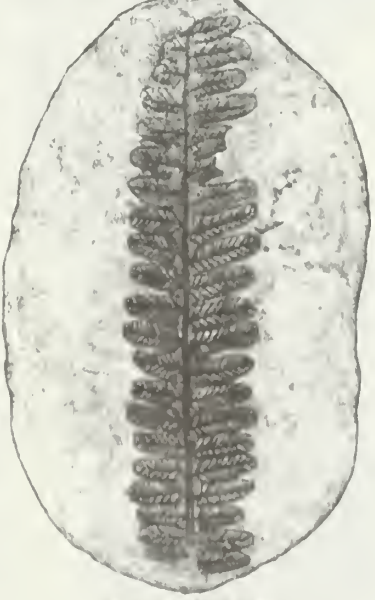
*Sphenophyllum cuneifolium* X0.4



*Pecopteris* sp. X0.32



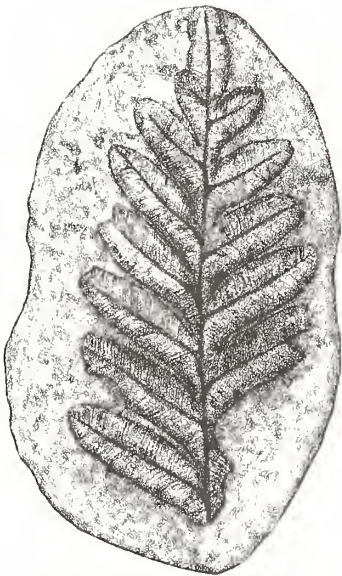
*Pecopteris miltonii* X2.0



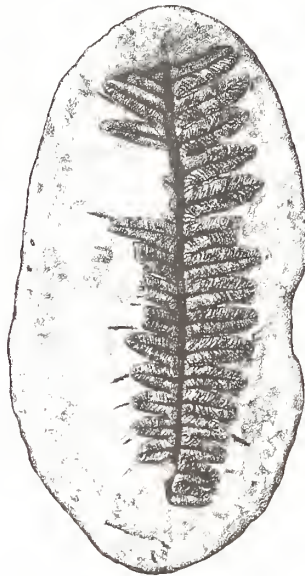
*Pecopteris hemitelioides* X1.0



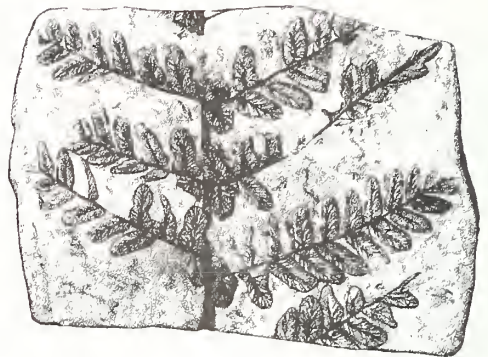
# Common Pennsylvanian plants: seed ferns and cordaites



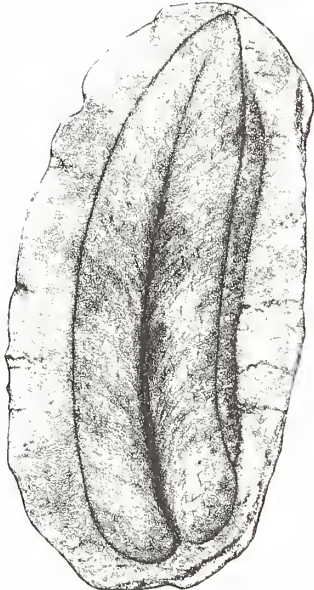
*Alethopteris serlii* X0.63



*Alethopteris ambigua* X0.63



*Neuropteris rarinervis* X0.5



*Neuropteris scheuchzeri* X0.63



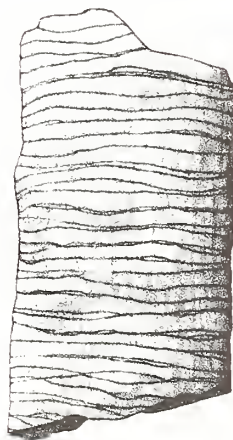
*Sphenopteris rotundiloba* X0.8



*Mariopteris nervosa* X0.8



*Cordaiacladus* sp. X1.0



*Artisia transversa* X0.63



*Trigonocarpus parkinsonii* X1.25



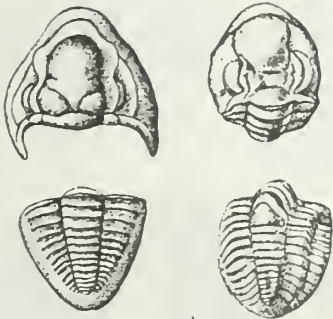
*Cordaicarpon major* X2.0



*Cordaites principalis* X0.63



### TRILOBITES



*Ameura sangamanensis*  $1\frac{1}{3}x$

*Ditomopyge parvulus*  $1\frac{1}{2}x$

### CORALS



*Lophophylidium proliferum*  $1x$

### FUSULINIDS



*Fusulina acme*  $5x$



*Fusulina girlyi*  $5x$

### CEPHALOPODS

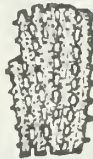


*Pseudarhoceras knaxense*  $1x$



*Glaphrites welleri*  $\frac{2}{3}x$

### BRYOZOANS



*Fenestrellina mimico*  $9x$



*Fenestrellina modesta*  $10x$

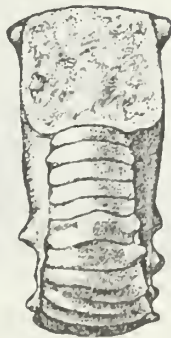


*Rhombopora lepidodendroides*

$6x$



*Metacaceros cornulum*  $1\frac{1}{2}x$



*Fistulipora carbanaria*  $3\frac{1}{3}x$



*Prismopora triangulata*  $12x$

## PELECYPODS



*Nuculo (Nuculopsis) girtyi* 1x



*Edmonio ovato* 2x



*Astortella concentrica* 1x



*Dunborella knighti* 1 1/2 x



*Cardiomorpha missouriensis*  
"Type A" 1x



*Cardiomorpha missouriensis*  
"Type B" 1 1/2 x

## GASTROPODS



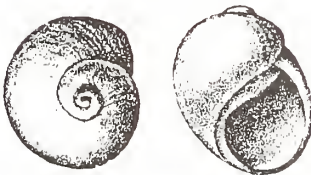
*Euphemites carbonarius* 1 1/2 x



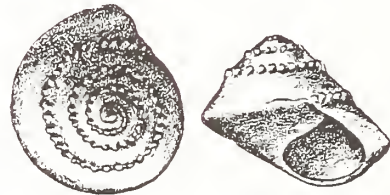
*Trepospiro illinoisensis* 1 1/2 x



*Donoldina robusta* 8x



*Noticopsis (Jedrio) ventricosus* 1 1/2 x



*Trepospira sphaerulata* 1x



*Knightites montfortianus* 2x



*Glabrocingulum (Globrocingulum) grayvillense* 3x

BRACHIOPODS



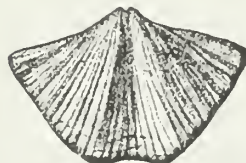
*Wellerella tetrahedra* 1 1/2 x

*Juresania nebrascensis* 2/3 x



*Derbya crassa* 1x

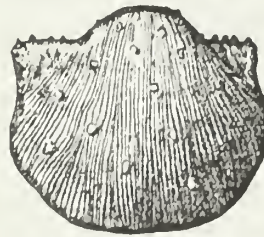
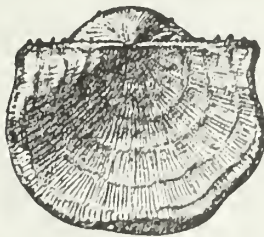
*Composita argentic* 1x



*Neospirifer cameratus* 1x



*Chonetes granulifer* 1 1/2 x *Mesolobus mesolobus* var. *evampygus* 2x *Marginifera splendens* 1x



*Crurithyris planoconvexa* 2x

*Linaproductus "coro"* 1x





## MISSISSIPPIAN DEPOSITION

(The following quotation is from Report of Investigations 216: Classification of Genevievian and Chesterian...Rocks of Illinois [1965] by D. H. Swann, pp. 11-16. One figure and short sections of the text are omitted.)

During the Mississippian Period, the Illinois Basin was a slowly subsiding region with a vague north-south structural axis. It was flanked by structurally neutral regions to the east and west, corresponding to the present Cincinnati and Ozark Arches. These neighboring elements contributed insignificant amounts of sediment to the basin. Instead, the basin was filled by locally precipitated carbonate and by mud and sand eroded from highland areas far to the northeast in the eastern part of the Canadian Shield and perhaps the northeastward extension of the Appalachians. This sediment was brought to the Illinois region by a major river system, which it will be convenient to call the Michigan River (fig. 4) because it crossed the present state of Michigan from north to south or northeast to southwest....

The Michigan River delivered much sediment to the Illinois region during early Mississippian time. However, an advance of the sea midway in the Mississippian Period prevented sand and mud from reaching the area during deposition of the St. Louis Limestone. Genevievian time began with the lowering of sea level and the alternating deposition of shallow-water carbonate and clastic units in a pattern that persisted throughout the rest of the Mississippian. About a fourth of the fill of the basin during the late Mississippian was carbonate, another fourth was sand, and the remainder was mud carried down by the Michigan River.

Thickness, facies, and crossbedding...indicate the existence of a regional slope to the southwest, perpendicular to the prevailing north 65° west trend of the shorelines. The Illinois Basin, although developing structurally during this time, was not an embayment of the interior sea. Indeed, the mouth of the Michigan River generally extended out into the sea as a bird-foot delta, and the shoreline across the basin area may have been convex more often than concave.

....The shoreline was not static. Its position oscillated through a range of perhaps 600 to 1000 or more miles. At times it was so far south that land conditions existed throughout the present area of the Illinois Basin. At other times it was so far north that there is no suggestion of near-shore environment in the sediments still preserved. This migration of the shoreline and of the accompanying sedimentation belts determined the composition and position of Genevievian and Chesterian rock bodies.

Lateral shifts in the course of the Michigan River also influenced the placement of the rock bodies. At times the river brought its load of sediment to the eastern edge of the basin, at times to the center, and at times to the western edge. This lateral shifting occurred within a range of about 200 miles. The Cincinnati and Ozark areas did not themselves provide sediments, but, rather, the Michigan River tended to avoid those relatively positive areas in favor of the down-warped basin axis.

Sedimentation belts during this time were not symmetrical with respect to the mouth of the Michigan River. They were distorted by the position of the river relative to the Ozark and Cincinnati shoal areas, but of greater importance was sea current or drift to the northwest. This carried off most of the mud contributed by the river, narrowing the shale belt east of the river mouth and broadening it west

of the mouth. Facies and isopach maps of individual units show several times as much shale west of the locus of sand deposition as east of it. The facies maps of the entire Chesterian...show maximum sandstone deposition in a northeast-south-west belt that bisects the basin. The total thickness of limestone is greatest along the southern border of the basin and is relatively constant along that entire border. The proportion of limestone, however, is much higher at the eastern end than along the rest of the southern border, because little mud was carried southeastward against the prevailing sea current. Instead, the mud was carried to the northwest and the highest proportion of shale is found in the northwestern part of the basin.

Genevievian and Chesterian seas generally extended from the Illinois Basin eastward across the Cincinnati Shoal area and the Appalachian Basin. Little terrigenous sediment reached the Cincinnati Shoal area from either the west or the east, and the section consists of thin limestone units representing all or most of the major cycles. The proportion of inorganically precipitated limestone is relatively high and the waters over the shoal area were commonly hypersaline... Erosion of the shoal area at times is indicated by the presence of conodonts eroded from the St. Louis Limestone and redeposited in the lower part of the Gasper Limestone at the southeast corner of the Illinois Basin...

The shoal area included regions somewhat east of the present Cincinnati axis and extended from Ohio, and probably southeastern Indiana, through central and east-central Kentucky and Tennessee into Alabama....

Toward the west, the seaway was commonly continuous between the Illinois Basin and central Iowa, although only the record of Genevievian and earliest Chesterian is still preserved. The seas generally extended from the Illinois and Black Warrior regions into the Arkansas Valley region, and the presence of Chesterian outliers high in the Ozarks indicates that at times the Ozark area was covered. Although the sea was continuous into the Ouachita region, detailed correlation of the Illinois sediments with the geosynclinal deposits of this area is difficult.

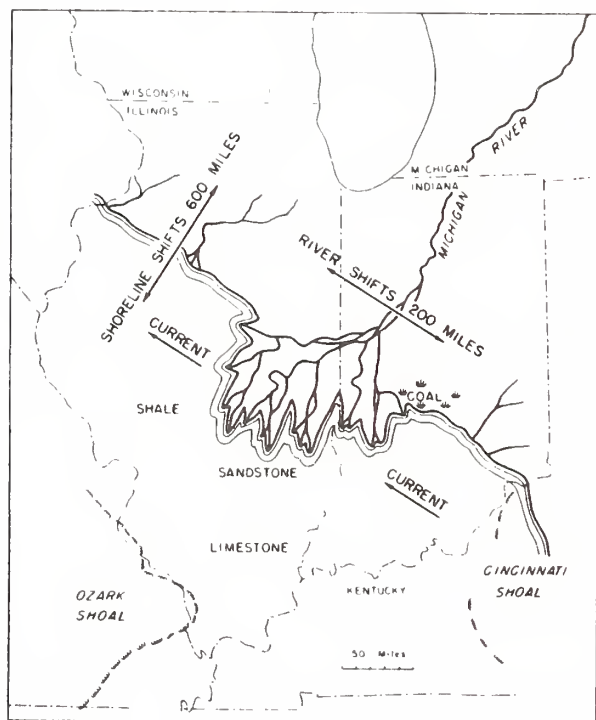


Figure 4: Paleogeography at an intermediate stage during Chesterian sedimentation.



# BRYOZOANS



*Rhombopora* 1x

# TRILOBITE



*Phillipsia* 1x

# CRINOIDS



*Pterotocrinus* 1x



*Platycrinus* 1x

# BLASTOIDS



*Pentremites* 2x



*Pentremites* 2/3x

# BRACHIOPODS



*Composita* 1x



*Leptaena* 1x



*Spiriferina* 1x



*Triplophyllites* 1x



*Brochthyris* 1x



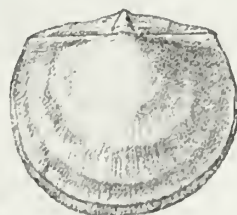
*Spirifer* 1x



*Girtyella* 1x



*Caninia* 2/3x



*Orthis* 1x



*Schuchertella* 1x



*Echinoconchus* 1x









